JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXIX. FEBRUARY, 1875. No. 2.

EDITORIAL.

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 20th, 1875.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last stated meeting, as likewise those of the special meeting held Wednesday, December 23d, 1874, were read and approved.

The Secretary then read the following

REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, FOR THE PROMOTION OF THE MECHANIC ARTS, FOR THE YEAR 1874.

Your Board report that during the year just passed 453 names have been added to the list of members, while but 11 resignations have been accepted, making an addition of four hundred and forty-two (442), an increase of 382 greater than during the year 1873. Of these nine (9) have purchased first-class stock, fifty-six (56) have purchased second-class stock, and six have become life members. This increase was due mainly to the recent exhibition, and partly to

exertions made by your Board to induce others than residents of Philadelphia to become members of our old and useful Institute. For the first time in many years a balance of any considerable amount stands to the credit of the Institute. The Treasurer's report tells us that the

Balance on hand Jan. 1st, 1874, was	$1,696·52
Receipts during the year, . .	112,408·59
Total, . . .	$114,105·11
Payments during the year, . .	52,769·02
Leaving a balance on hand of .	$61,336·09

The Treasurer has furnished your Board with a statement of the indebtedness of the Institute, which amounts to about $21,837·07. The means to meet said indebtedness, January 1st, 1875, were as follows:

U. S. 6 per cent. Loan, . .	$6,000·00
Cash on Hand, . . .	61,336·09
	$67,336·09

The above means do not include the value of the Hall, Library, and collection of the Institute.

The Committee on Publication make the gratifying statement that the JOURNAL OF THE INSTITUTE has this year cleared its expenses, although in such expenses have been estimated the salary of the editor for part of the year.

Additions have been made to the library of

Bound Volumes, ...	77
Unbound, including Journals, Pamphlets, Proceedings of Societies, etc., . .	123
British Patent Specifications, estimated, .	100
Total, ...	300

The drawing school, during the spring term, was under the charge of Prof. Alfred C. Wernicke, and was attended by seventy-six pupils. During the summer it was found that the services of Prof. L. M. Haupt could be secured, and the drawing school arranged in classes under competent assistants. This plan has proved very advantageous,

and the attendance during the fall term was increased to one hundred and thirty-two (132) pupils.

In last year's report allusion was made to gentlemen who volunteered as lecturers, *i. e.*, who gave their services for the good of the Institute, and their names were mentioned in the yearly report. The list in the fall course was headed by Prof. Robert E. Rogers, M. D., as a volunteer, and during the term of 1874-75. Dr. Henry Leffman, Mr. S. Lloyd Wiegand, Mr. J. B. Knight, and Mr. Robert Grimshaw also are in the list of volunteers. Valuable lectures were delivered by Prof. E. J. Houston, and Prof. Harrison Allen is yet to lecture.

The important event of the year was the holding of the twenty-seventh exhibition of the Institute. In order that a statement of this event could be presented to you in a succinct form the chairman of the Committee on Exhibition, Mr. Wm. P. Tatham, was requested to draw up a report, which was accepted by the Board of Managers and ordered to be made a part of this report. It is as follows:

To the Board of Managers of the Franklin Institute:

The Committee on Exhibitions, which, under existing By-Laws, is a Committee of your body, respectfully report:

That the Exhibition of 1874, held to celebrate the Fiftieth year of the Foundation of the Institute, proved worthy of the occasion, whether its success be tested by the number and excellence of the articles exhibited, the large concourse of visitors, the instruction and gratification it afforded to the community, or by the pecuniary results.

The first movement towards the Exhibition was at the stated meeting of the Institute held February 18, 1874, when, on motion of Mr. G. Morgan Eldridge, the subject was referred to the Committee on Exhibitions.

The Committee lost no time in addressing a letter to J. Edgar Thompson, Esq., late President of the Pennsylvania Railroad Company, making an application for the use of their depot on Market Street, between Thirteenth and Juniper Streets, for the purpose of an Exhibition. This application having been laid before the Board of Directors, and favorably entertained by it, the President (Mr. Thompson) was authorized to act, which he did by the letter of his assistant, Strickland Kneass, Esq., dated the 17th of March, placing

the depot at our disposal during the months of September and October, 1874. Thus, by the exercise of the greatest liberality on the part of the Pennsylvania Railroad Company, the Institute had, for the first time for many years, the opportunity of holding an Exhibition under promising conditions.

At the stated meeting of the Institute held the 18th of March, resolutions were adopted, requesting the Board of Managers to hold an Exhibition, and to secure a guarantee fund to indemnify the Institute against loss. This condition having been fulfilled, public announcement was made upon the 14th of April, that the Exhibition would be held from the 6th to the 31st of October, thus allowing thirty-five days for the transformation of the building and preparation for the Exhibition, and twenty-six days for the Exhibition itself.

Your Committee, before this time, had been strengthened by adding to it all the members of the Board of Managers, and the assistance of the Institute at large was invoked, resulting in the appointment by the President of one hundred members, for the purpose of forming Committees on the various classes of Exhibits. Some of these gentlemen were appointed upon the standing sub-committees, and acted with the greatest ability, zeal and usefulness. The Class Committees were composed, when possible, of members associated with the various trades and industries. It was made their duty to stimulate exhibitors in their respective classes, and thus to induce an Exhibition which would command the public attention and secure success.

These Committees were also requested to nominate the Judges in their respective classes. It is believed that the policy thus adopted for the first time, had a large influence upon the ultimate success of the Exhibition.

The Committees on Rules, Transportation, and Publication having completed their preparations, a pamphlet containing an address by the Board of Managers, with the necessary information and the Rules governing the Exhibition, was issued upon the 13th of May. The duties of the Committee on Space then began, and were continued all summer, culminating at the opening of the Exhibition. On the 1st of July, Mr. J. B. Knight, who had been actively performing committee work as a member of the Institute, was appointed General Superintendent of the Exhibition.

The Pennsylvania Railroad Company had conditionally promised the use of the depot from the first of September, and the surveys and

preliminary arrangements were made by the Sub-Committee on Building and Machinery to accomplish its work in the interval of time allowed it. But, actually, the Company abandoned the depot upon the 19th of August, and we were placed in possession twelve days before the time specified. The advantage thus gained was never lost. The Sub-Committee pushed the work with such energy that the Exhibition building was ready to receive goods about the 1st of September, instead of the 14th, as advertised.

The Committee had been led to expect that the patent boilers to be exhibited would be sufficient to run the machinery of the Exhibition; but it became apparent towards the end of September that this reliance would fail, and arrangements were made to secure other boilers, which were placed outside of the building. In consequence of this disappointment, the steam-power was not ready until the day after the opening of the Exhibition. Considering, however, the great number of Exhibits and the unusual number of machines in motion, the general preparation of this Exhibition was unusually prompt.

The Exhibition was opened by the Governor of the State of Pennsylvania, upon the day appointed, and attracted the sustained attention of the public to such an extent, that it was deemed advisable to continue it open for twelve days longer than was originally designed.

The principal reasons for this extension (which on general principles should be avoided) were, that the great crowds of visitors made it impossible for the Judges to perform their duties satisfactorily, and the same cause excluded from the Exhibition many persons who had bought tickets of admission, over 12,000 of which were outstanding in the hands of the community at the end of October.

The greatest number of tickets paid for and unused, at any one time, was 31,973, upon the 20th of October.

At the close of the Exhibition the number still outstanding was 4120.

The whole number of paying visitors was 267,638, besides members of the Institute, their ladies, and minors, and persons admitted on complimentary tickets issued to the press and to others whose liberality it was desired to recognize. Making due allowance for these, it may be said that the Exhibition was visited by one-third of our population. The number of applications for space was 1528. The number of entries for exhibition, many of them covering numerous items and large displays, was 1251. The number of steam boilers

in operation was 9, of 316 horse-power in the aggregate, consuming 267 tons of coal. There were 3 steam engines driving shafting, 22 driving pumps, and 11 driving particular machines. The whole number of steam engines at work, or in motion, was 46. The whole number of machines in motion was 281.

Some of the displays were of peculiar excellence. The photographs were particularly good, and would class strictly with the fine arts; but besides these, the variety and beauty of the chemicals displayed, the wonder working of the sewing machines, the brilliancy of the saws, the splendor of the chandeliers, the rapidity of the printing press, the precision of movement of the machine tools, and the truth and finish of the paper cylinders, appealed not only to our appreciation of the usefulness of these exhibits, but in addition lent to them the charms and influences of the fine arts.

As a further testimony to the excellence of the exhibition, it appears that although the rule upon the subject of premiums, prepared by the proper committee and adopted by the Board of Managers, was more severe than usual, the premiums awarded under it were more numerous than at any previous exhibition; being 201 silver medals, 228 bronze medals, and 222 certificates of honorable mention, in all 651, while many subjects were recommended to the Committee on Science and the Arts, for the award of the special medals of the Institute.

It is impossible now to state the exact financial results of the exhibition, because some bills are not yet adjusted, and some expenses are still to be incurred. We received for entry account, pulley account, and sale of tickets, $91,947.61, and our expenses are already $37,664.95, and it is estimated they will reach $39,775.95, leaving the sum of $52,171.66 as net profits. It is proposed to publish a full report, embracing the reports of the judges and all matters connected with the Exhibition.

The results of our efforts prove the readiness of our people to visit a meritorious Exhibition, and should encourage the Managers of the great Centennial in hoping for a magnificent success to their undertaking.

It remains to record our thanks to those persons whose liberality, or kindness has assisted us in various ways. The thanks of the Institute are due to the authorities of the Pennsylvania Railroad Company, whose liberality already noticed was followed by repeated acts

of like character and by acquiescence in all our requests; to the subscribers to the guarantee fund, who afforded us the first encouragement, a like acknowledgment is none the less due, because the result has exempted them from all liability.

We owe our thanks also to His Honor, the Mayor of the City, for an efficient police force during the Exhibition, and to all the Departments of the City government to whose good offices we were indebted; to the Navy Department for the flags used in decoration, and to the Treasury Department for the deposit of the life boat at our request; to Messrs. Morris, Tasker & Co. for the liberal use of their gas pipes, and to Messrs. Wm. C. Allison & Sons for a like use of steam pipes, to the American Dredging Co. for the free loan of a new boiler, and to Messrs. I. P. Morris & Co. for a like favor.

It is proper, also, to thank many of the exhibitors who incurred considerable expense merely to serve the purposes of the Exhibition. Among these were Messrs. Jacob Naylor, Andrew Watson, Neafie & Levy, and Robert Wetherill, exhibitors of steam engines; Messrs. Wm. Sellers & Co. and Geo. V. Cresson, exhibitors of shafting; Messrs. Thomas J. Rorer, Sellers & Bros., and Alexander Bros., exhibitors of belts; all used in driving the machinery of the Exhibition. Our thanks are also due to Mr. Thomas Shaw, who at our suggestion exhibited a much larger propeller pump and cataract than he had designed; to Mr. Charles H. Brown for a pump used to supply the outside boilers; to Messrs. Dyott & Co. for the liberal loan of street and door lamps; to Messrs. Cornelius & Sons, Baker, Arnold & Co., Thackara, Buck & Co., and the American Reflector Co., for the loan of gas fixtures; to Messrs. I. P. Morris & Co., who at our request built the fast Bullock printing press and engaged to carry it until sold, in order that it might be placed in the Exhibition; to the judges (not necessarily members of the Institute), who brought to their delicate tasks a special knowledge of the subjects committted to them, and performed their duties with the greatest integrity, assiduity and judgment; and finally, to the public press, which, recognizing the public nature of our enterprise, was a faithful interpreter of the kind feeling of the community towards us.

The labor performed by the sub-committees, particularly by those upon Building and Machinery, and upon Space, were of a character which it would be impossible to buy.

The officers employed in the Exhibition performed their duties with the greatest efficiency, and the Committee take especial pleasure in testifying to the ability, energy and tact of the General Superintendent.

W. P. TATHAM,
Chairman Committee on Exhibitions.

Philadelphia, Jan. 18, 1875.

Your Board submit with this report an official statement of the awards to the exhibitors as confirmed by them, premising the list by the explanation that in the report to be published, which will embody the reports of the Judges, much valuable matter will be given, and mention will be made of all articles entered in competition, many of those not receiving premiums being favorably mentioned.

All of which is respectfully submitted.

By order of the Board.

COLEMAN SELLERS, *President.*

The Report of the Board as read was accepted, and ordered to be published in the JOURNAL.

Mr. S. Lloyd moved that the publication of that portion of the Report referring to the awards be withheld from the public press until certain matters in dispute should be satisfactorily adjusted, and supported the motion in an address, setting forth his reasons therefor. The motion was seconded by Mr. Woodruff, who remarked that many of the dissatisfied exhibitors had not as yet had the opportunity to enter reclamation.

The motion was put to the meeting and lost.

The Actuary then reported the minutes of the Board of Managers, and of the several Standing Committees. He also reported that at the stated meeting of the Board, held Wednesday, the 13th inst., the following donations to the Library had been reported, viz. :—

Journal of the Chemical Society for August, September and October, 1874. From the Society.

Journal of the Statistical Society for September, 1874, with a General Index to Vols. 26 to 35, 1863 to 1872. From the Society.

The Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions. Chief Engineer's Monthly Report for September, 1874. From the Association.

Proceedings of the Scientific Meetings of the Zoological Society of London for the year 1874. Parts 2 and 3. From the Society.

Proceedings of the Royal Institution of Great Britain, Vol. 7, Parts 3 and 4. From the Institution.

Annales des Ponts et Chaussées for September, 1874. From the Editor. Paris.

Annales de Chimie et de Physique for September, 1874. From the Editor. Paris.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, Vol. 1, Nos. 9–10. From the Society.

Remarks to accompany Monthly Charts of Meteorological Data for Square 3. From the Meteorological Office. London.

Quarterly Weather Reports of the Meteorological Office. Part 4, October to December, 1871. Part 3, July to September, 1873. From the Meteorological Office.

Charts of Meteorological Data for Square 3, Lat. 0° to 10° N., Long.20° to 30° W. From the Meteorological Office.

Report of the Commissioner of Education for 1873. Washington, 1874. From the Commissioner.

Monthly Notices of the Royal Astronomical Society, Vol. 35, No. 1, November, 1874. From the Society. London.

Annales de Chimie et de Physique for October and November, 1874. From the Editor. Paris.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale for November, 1874. From the Society. Paris.

Publishers' Trade List Annual, embracing the full Trade Lists of American Publishers. From J. B. Lippincott & Co. Philadelphia.

Forty-first Annual Report of the Royal Cornwall Polytechnic Society, 1873. From the Society.

Smithsonian Contributions to Knowledge 281, on the General Integrals of Planetary Motion. By Simon Newcomb, Professor of Mathematics, U. S. N. From the Smithsonian Institution.

Treatise on Elements of Mechanics. By John W. Nystrom, C. E. From the Author.

On the Diurnal Inequalities of the Barometer and Thermometer. By W. W. Rundell, F. M. S. From the Author.

Dr. Robert E. Rogers, as Chairman of the Special Committee to prepare a suitable testimonial to the Pennsylvania Railroad Company, in acknowledgment of their kind offices in placing the Freight Depôt at Thirteenth and Market Streets at the disposition of the Institute

for Exhibition purposes, presented the following preamble and resolutions, which, on motion, were unanimously adopted, viz.:

WHEREAS, The Franklin Institute, recognizing the great progress made in the Mechanic Arts since the holding of the last Exhibition in 1858, and feeling impressed with the importance of having an Exhibition during the autumn just passed, not only for the immediate benefit expected to the Institute and to the community at large, but also as a preparation for greater results at the Centennial, was anxiously seeking a building suitable for such an Exhibition,

AND WHEREAS, The Pennsylvania Railroad Company, alive to the interests of the City and the State, with its accustomed public spirit and liberality, placed at the service of the Institute without rent or charge of any kind, their spacious Depot Building at Thirteenth and Market Streets,

AND WHEREAS, Without such liberality the Institute could not have held its recent Exhibition; therefore,

Resolved, That the cordial thanks of the Franklin Institute be tendered to the President and Board of Directors of the Pennsylvania Railroad Company for this act of generous kindness, which has enabled the Institute to hold an Exhibition surpassing in attractiveness and success any it has held in previous years.

Resolved, That the Institute will ever hold in grateful recognition the cordial sympathy manifested by the Pennsylvania Railroad Company in the great interests which the Franklin Institute represents.

Resolved, That the Institute desires to express its thanks also to the subordinate officers of the Pennsylvania Railroad Co. for the cheerful co-operation which it has received at their hands.

R. E. ROGERS (Ch.), COLEMAN SELLERS,
W. P. TATHAM, CHAS. S. CLOSE,
J. B. KNIGHT, HECTOR ORR. *Committee.*

Mr. J. W. Nystrom, on behalf of the Committee on New Site and Building, reported progress. The report of the Secretary was, on motion, passed over.

Under the head of deferred business, the resolution of Mr. Shaw to appoint a committee of appeal to hear and adjust disputed matters growing out of the awards made at the late exhibition; and likewise, the amendment of Mr. Burleigh, to refer the subject to arbitration before the Committee on Science and Arts, both of which were

postponed from the last stated meeting, were called up for consideration.

Mr. Shaw urged the passage of the resolution as offering the only satisfactory solution of existing difficulties, and employing substantially the same arguments as those advanced at the previous meeting.

Mr. William P. Tatham deprecated any further agitation of the subject. He spoke earnestly against the resolution, dwelling upon the patient labor that had been bestowed upon the reports of the Judges by the Board, and of the impossibility of satisfying every one in an enterprise of the magnitude of the late exhibition.

Mr. Hector Orr spoke of the inutility of handing the subject over to the Committee on Science and Arts. The amendment of Mr. Burleigh to so refer the resolution was then put to vote, and lost.

Mr. Orr then offered the following amendment to the resolution, viz.:—

WHEREAS, Certain complaints have been offered against the awards and decisions of the proper authorities of the late Industrial Exhibition held by the Franklin Institute,

AND WHEREAS, The ascertainment and correction of said grievances are alike the duty and interest of the Institute, therefore

Resolved, That a committee of members be appointed to hear the above charges and report thereon to the Institute as early as possible, *provided* that no Manager, nor Judge, nor any complaining depositor shall be eligible to serve on said Committee, but all these excluded classes shall be entitled and invited to testify before said Committee upon the subjects involved.

The amendment was discussed by Messrs. Shaw, Gray, Close and the mover, and on being put to the house was lost.

Mr. Frederick Fraley next addressed the meeting in opposition to Mr. Shaw's resolution, which he characterized as being entirely without precedent, and revolutionary in its character. He moved the previous question, which being duly seconded was put to vote and ordered. The resolution was lost.

A communication of Mr. Gravenstine was then called up under deferred business, but was withdrawn.

Mr. William B. LeVan, under new business, offered the accompanying amendments to the By-Laws, which in accordance with Article XVI., were laid over until the stated meeting of February, viz.:

Resolved, That Section 3, Article 5, of the By-Laws be amended by changing the hour of opening the polls from 4 o'clock to 3 o'clock

P. M., and the hour of closing the polls from 8 o'cock to 9 o'clock P. M.

Resolved, That Section 1 of Article 5 of the By-Laws be amended by adding to the first sentence the following: "And provided further that no member shall be eligible for re-election as a Manager or Vice President, for the period of one year after his term of office has expired."

Mr. Thomas Shaw then moved that a committee be appointed to prepare and submit to the Institute the draft of a section to the By-Laws making provision for a Board of Appeal for the adjustment of difficulties growing out of the exhibitions of the Institute.

Mr. Lippman amended the resolution by the clause, "that five members be appointed by the meeting, who, in conjunction with a similar committee from the Board of Managers, shall consider the expediency of revising or amending the modes, rules and regulations governing awards, and report to the Institute upon the system which they shall deem the most perfect."

The amendment and resolution were respectively put to vote and lost.

Mr. Sellers then resigned his seat to the senior Vice-President, Mr. Bloomfield H. Moore, and after calling attention to the somewhat dilapidated condition of the chair which he, as well as numerous predecessors, had so long occupied, moved that the proper authorities be directed to purchase a new one for the incoming President. Carried.

Mr. B. H. Moore next occupied the floor eulogizing the services of a number of gentlemen who were active in contributing to the success of the late exhibition. He offered the following resolution:

Resolved, That the thanks of the Institute be tendered to Messrs. Tatham, Close, Knight, Bullock, Sartain, and others, for their services in behalf of the Exhibition. Carried.

The judges of the election next announced the result of the balloting for officers, whereupon the President declared the following gentlemen to have been elected to the offices opposite their names, viz:

President, Professor Robert E. Rogers.

Vice-President, Charles S. Close.

Secretary, J. B. Knight.

Treasurer, Frederick Fraley.

Managers to serve three years, Coleman Sellers, William P. Tatham, Washington Jones, Pliny E. Chase, J. M. Wilson, Dr. Isaac Norris, Jr., George F. Barker, Theodore D. Rand.

Manager to serve two years, Alexander Purves.

Auditor, James H. Cresson.

A motion was made, and unanimously carried, that the thanks of the Institute be tendered to Mr. Coleman Sellers, the retiring President, for the efficient and satisfactory manner in which he had presided over the meetings of the Institute, during his term of office.

A vote of thanks to the other retiring officers, was also unanimously carried.

Whereupon the meeting adjourned.

WILLIAM H. WAHL, *Secretary.*

FRANKLIN INSTITUTE EXHIBITION, 1874, AWARDS OF PREMIUMS.

I.—Agricultural Implements.

SILVER MEDAL.

353	Graham, Emlen & Passmore, Philadelphia,	The Philadelphia Lawn Mower.
981	Samuel L. Allen & Co., "	The Planet Drill & Wheel Hoe.

BRONZE MEDAL.

94	Wm. L. Boyer & Bro., Philadelphia,	Burt's Union Railway Horse Power.

HONORABLE MENTION.

254	B. Gill & Sons, Trenton, N. J.,	Rye Thresher.
706	John M. Hess, Philadelphia,	Pat. Self-Watering Hanging Basket.

II.—Agricultural Productions.

SILVER MEDAL.

522	Duryea Glen Cove Starch Co., New York,	Improved Corn Starch.
20	Duryea Glen Cove Starch Co., New York,	Satin Gloss Starch.
489	C. J. Fell & Bro., Philadelphia,	Spices and Mustard.

BRONZE MEDAL.

78	Lagomarsino & Cuneo, Philadelphia,	Maccaroni, Verm'li & Fancy Paste.
669	E. M. Dexter, Philadelphia,	Ornamental Confectionery.
237	G. Boyd, Philadelphia,	Grubb's Aroma Coffee Cooler.
238	" "	Aroma Coffee Roaster.
1492	H. Troemner, Philadelphia,	Coffee Mill.
209	Mrs. Joshua Wright, Philadelphia,	Mince Meat.
416	D. Carrick & Co., "	Crackers, Cakes and Biscuits.
664	Theo. Wilson & Co., "	Crackers and Cakes.
740	Godfrey Keebler, "	Cakes and Crackers.
946	Woodward, Garrett & Co., Philadelphia, for Edw. Holbrook, M'f'r, Louisville, Ky.,	Manufactured Tobacco.
267	S. Fuguet & Sons. Philadelphia,	Seidenberg & Co's, Key West, Havana Cigars.
1454	Frishmuth, Bro. & Co , Philadelphia,	Fine Cut Tobacco, " Luxury."

HONORABLE MENTION.

270	Atmore & Sons,	"	Plum Puddings.
1309	John A. Place, Phila., for F. E. Smith Co., Manufacturer, New York,		Crushed White Wheat.
980	Lagomarsino & Cuneo, Philadelphia,		Farina.

III.—Arms and Military Goods.

BRONZE MEDAL.

951	Wm. Wurflein, Philadelphia,		Creedmore or Parlor Rifle.

HONORABLE MENTION.

1019	John Krider, Philadelphia,		Guns and Sporting Instruments

IV.—Books and Stationery.

SILVER MEDAL.

742	J. B. Lippincott & Co.,		Blank Books and General Binding.
743	Byron Weston, Dalton, Mass.; J. Shoemaker, Agent,		Linen Ledger and Record Paper.
39	Jos. E. Hover & Co., Philadelphia,		Chemical Writing Fluids.
699	Wm. F. Murphy's Sons,	"	Blank and Copying Books.
1493	Wm. Mann,	"	Copying Paper.

BRONZE MEDAL.

331	Crane Bros., Westfield. Mass.,		Various articles m'f'd fr. Paper Pulp.
942	Jno. E. Potter & Co., Philadelphia,		Potter's Complete Bible Encyclopedia.
455	Ig. Kohler,	"	Book Binding.
644	Esterbrook Steel Pen Co., Camden, N. J.,		Steel Pens.
686	Porter & Coates, Philadelphia,		Book Binding.
1512	J. B. Lippincott & Co., Philadelphia,		Book Printing.
803	Fry's Engraving Office,	"	Book Binders' Tools and Dies.
44	Altemus & Co.,	"	Photograph Albums.
1003	Geo. W. Woolley,	"	Pat. Reservoir Pen.

HONORABLE MENTION.

264	Lipman Manufacturing Co., Philadelphia,		Hover's Carbonized Writing Paper.
941	John E. Potter & Co.,	"	Brown's Self-Interpreting Bible.
943	" "	"	Blackwood's Comprehensive Bible.
403	T. Ellwood Zell,	"	Books of Reference.
819	A. J. Holman & Co.,	"	Illus. Fam. Bibles & Photo. Albums.
861	Chas. Magarge & Co.,	"	Jessup & Laflin's Writing Paper, (Westfield, Mass.)
1354	Louis Dreka,	"	Dictionary Blotter.
265	Lipman Manufacturing Co.,	"	Lipman's Pat. Eyelet Machine.

V.—Boots and Shoes.

SILVER MEDAL.

303	C. Benkert & Son, Philadelphia,		Gents' Hand-made Boots and Shoes.

BRONZE MEDAL.

2	Thos. R. Evans, Philadelphia,		American Gaiter.
983	Saller, Lewin & Co.,	"	Machine-made Boots and Shoes.
184	M. A. Erskine & Co.,	"	Ladies' Hand-made Boots and Shoes.
1021	Royal & Reed,	"	Ladies', Misses', and Children's Machine-made Boots and Shoes.

HONORABLE MENTION.

207	Wm. F. Bartlett, Philadelphia,	Gents' Boots and Shoes.
483	Porous Waterproofing Co., Philadelphia,	Water Proof Boots and Shoes.
936	Wm. G. Schoell, "	Hand-made Seamless Boots & Shoes.
1484	A. C McKnight, "	Water Repellant Boots and Shoes.
1236	Allen, Gates & Bro., "	Ladies' Machine Sewed Lined Boots and Shoes.

VI.—Cabinet Ware and Upholstery.

SILVER MEDAL.

411	Hale, Kilburn & Co., Philadelphia,	E. E. Everett's Pat. Fold. Bedstead.
208	Jas. S. Earle & Sons, "	Mirrors, Picture Frames, etc.
219	Jos. W. Cooper, "	Fancy Walnut Brackets, etc.
524	Allen Bro's, "	Parlor Furniture, etc.

BRONZE MEDAL.

336	Fred. Boland, Philadelphia,	Mirrors and Picture Frames.
252	J. A. Bancroft & Co., Philadelphia,	Imp. Rever. Settee, T. J. Close, Pat.
521	R. W. P. Goff, "	Fancy Walnut Brackets, etc.
311	Chas. W. O'Hara, "	Comfortable Chair.
415	A. Lowe & Co., "	Mirror and Picture Frames, etc.
745	Hutchins & Mabbett, "	Gardner's Pat. 3 ply Veneer Chairs.
1352	Thos. Potter, Sons & Co., "	Knapp's Spring Balance Roller.
410	Hale, Kilburn & Co., "	Pat. Flexible Wood Seat Chair.
414	Kilburn & Gates, "	Cottage Furniture.
549	H. B. Coyle, "	Centennial Iron Bedstead.
61	Samuel McCracken, "	Inlaid Centre Tables.
879	Cyrus Horne, "	Burial Casket.
3	W. B. Coates, "	Convertible Folding Lounge.

HONORABLE MENTION.

412	Hale, Kilburn & Co., Philadelphia.	H. W. Curtis, Pat., Walnut Mats for Picture Frames.
201	Salem Shade Roller Mfg. Co., exhibited by E. S. Johnston,	Window Shade Balance Spring Roller Attachment.
149	C. Faser, Philadelphia,	Gilt Frame Mirror, fine finish.
175	Carrington, DeZouche & Co., Philadelphia,	Handsome Display of Curtains.
188	W. Heacock, Philadelphia,	Fine Finish of Furniture.
413	Hale, Kilburn & Co., Philadelphia,	Walnut Looking Glass and Picture Frames.
125	Walter & Stoeltz, Philadelphia,	Show Case.
433	G. J. & J. A. Henkels, Philadelphia,	Design and Fine Finish of Chamber Furniture.
689	Jno. McKinley, "	Parlor Furniture.
638	S. B. Register, Philadelphia,	Furniture.
1426	James Irons, "	Show Cases.

VII.—Carpets, Oil Cloths, and Floor Coverings.

SILVER MEDAL.

1105	Bromley Bro's, Philadelphia,	Patent Imperial Damask Venetian Carpets.
400	Thos. Potter, Son & Co., Philadelphia,	Table and Enameled Oil Cloths.
59	Reeve L. Knight & Son, "	Display of Carpets from various Mfrs.
1257	" " "	A. Smith & Son, Axminster Carpets.

BRONZE MEDAL.

709	John Bromley & Sons, Philadelphia,	Ingrain and Damask Carpets.

HONORABLE MENTION.

516	G. W. Chipman & Co., Boston, Mass.,	Carpet Linings.

VIII.—China, Glass, and Porcelain.

SILVER MEDAL.

728	Ward & Co., Philadelphia, for Lenox Plate Glass Co., Mass.,	Rough Plate Glass.
1153	J. & G. H. Gibson, Philadelphia,	Stained Glass.

BRONZE MEDAL.

224	Jas. K. Kerr & Bro's, Philadelphia,	Decorations on China.
490	J. K. Dunham, Agent for Boston & Sandwich Glass Co.,	Glassware.
595	Whitall, Tatum & Co., Philadelphia,	Glassware.
900	S. G. Boughton, Philadelphia, Agent for New England Glass Co.,	Glassware.
708	Dempsey Wicker Covered Glassware Co., Philadelphia,	Wicker Covered Bottles.

HONORABLE MENTION.

174	J. E. Jeffords & Co.,	Philadelphia,	Yellow, Rockingham, Birmingham, and Lava Wares.
213	Wm. Holzer,	"	Display of Glassware, Medical and Philosophical Apparatus.
398	Jas. K. Kerr & Bro's,	"	Engraving on Glass.
1375	Hartell & Letchworth,	"	Sand Blast Glass Work.
1424	Cohansey Glass Co.,	"	Fruit Jars.
120	Richard C. Remmey,	"	Chemical Stone Ware.

IX.—Coach Work.

SILVER MEDAL.

1292, 1293, 1294	Wm. D. Rogers & Co.,	Philadelphia,	Carriages.
79	W. Garner & Son,	"	Light Business Wagon.
43	Fulton & Walker,	"	Omnibus.
431	" "	"	Express Wagon.
301	Geo. Lengert & Son,	"	Truck Wagon.
235	Harry J. Shill,	"	Children's Carriages.
715	Benezet & Co.,	"	Coach, Carriage, and Wagon Springs.
198	Wm. Burwell & Bro.,	"	Carriage Mountings.

BRONZE MEDAL.

277	Wm. D. Gardner,	Philadelphia,	Carriages.
87	S. P. Campbell & Co.,	"	Children's Carriages.
909	W. & H. Rowland,	"	Coach, Carriage, and Wagon Springs.

HONORABLE MENTION.

519	S. W. Jacobs & Son,	Philadelphia,	Carriages.
481	Jas. Fleming,	"	Carriages.
527	Weaver & Lyle,	"	No-top Wagon.
164	Geo. K. Childs,	"	One-man Wagon.
262	McLear & Kendall.	"	Carriages.
334	Collings Bros.,	"	Carriages.
882	George Tiel,	"	Child's Sleigh.
15	The Phila. Axle Works,	"	Carriage and Wagon Axles.
1457	Advena & Heald,	"	Carriage and Wagon Axles.
616	Hoopes Bro's & Darlington,		Carriage and Wagon Wheels.
1414	Hoopes Bro's & Darlington,	West Chester, Pa.,	Bent Carriage Material.
1208	W. Garner & Son,	Philadelphia,	Hand-made Wheels.
988	S. D. Mott, Milford, Pa.,		Pat. Guiding Attachment for Coasting Sleigh.

Awards of Premiums.

X.—Coal and Minerals.

SILVER MEDAL.

632	James C. Hand & Co., Philadelphia,	Corundum, from Pa. Corundum Co.

HONORABLE MENTION.

1364	Denver and Rio Grande R. R. Co.,	Coal and Coke.

XI.—Combs and Brushes.

SILVER MEDAL.

928	Chas. Brintzinghoffer, Philadelphia,	Leather Back Horse Brush.

BRONZE MEDAL.

635	Geo. W. Metz & Sons, Philadelphia,	Fine toilet and other Brushes.

XII.—Copper, Brass, Plumbers' and Tin Ware.

SILVER MEDAL.

560	Joseph L. Travis, Philadelphia,	J. & H. Jones' Ne Plus Ultra Water Closet.
1070	Miller & Krips, "	Brass Castings.

BRONZE MEDAL.

112	Cooper, Jones & Cadbury, Philadelphia,	Water Closet Valve.
280	" " " "	Compression Bibb Cocks.
559	Joseph L. Travis, "	Combination Shower Cock.
1249	John P. Schaum, Lancaster, Pa.	Copper Kettle.
1222	Chas. Burnham & Co., Philadelphia,	Patent Safety Can.
1320	W. S. Bate, Philadelphia,	Patent Wash Stand Faucet.
1480	Philadelphia Smelting Co., Philada.	Unfinished Brass & Bronze Castings.
1101	N. & G. Taylor Co., "	Decorated Tin Plates.

HONORABLE MENTION.

124	R. D. O. Smith, Washington, D. C.	Odorless Water Closet and Urinal.

XIII.—Cotton and Woolen Goods.

SILVER MEDAL.

1503	Washington Mills, Lawrence, Mass., Jas. W. Dayton, Agent,	Superior Worsted Coatings.
1504	Washington Mills, Lawrence, Mass., Jas. W. Dayton, Agent,	Superior Colors in Shawls and Dress Goods.
1505	Burlington Woolen Co., Winooski Falls, Vt., Jas. W. Dayton, Agent,	Superior Wool-dyed Kerseys.
1506	Burlington Woolen Co., Winooski Falls, Vt. Jas. W. Dayton, Agent,	All-wool Black and colored Cloths, Doeskins and Beavers.
103	Fiss, Banes & Erben, Philadelphia,	Jennapped Worsted Yarn.
104	" " " "	No. 120 Worsted Yarn.*
729	David Trainer & Sons, Linwood, Pa.	Superior Extra Omega Tickings.
1227	Willimantic Linen Co., Colladay, Trout & Company, agents,	Spool Thread.
85	S. B. & M. Fleisher,	Star Alpaca Braids.
16	Aub, Hackenburg & Co.	Machine and Sewing Silks. Black and White
478	Belding Bros. & Co., L. C. Hall, Jr. & Co., Agents,	50 and 100 yards Sewing Silks, plain and Fancy Colors.

* The exhibit of No. 120 Worsted Yarn has been referred to the Committee on Science and Arts, with recommendation that it be awarded one of the higher medals of the Institute.

BRONZE MEDAL.

651	Wood & Haslam,	Quilts.

HONORABLE MENTION.

1059	David S. Brown & Co. (Gloucester and Ancona Printing Co.,)	Display of Prints.

XIV.—Dental and Surgical Instruments.

SILVER MEDAL.

62	S. S. White, Philadelphia,	Artificial Teeth.
779	D. W. Kolbe, "	Artificial Limbs.
1517	" " "	Surgical Instruments.
1478	S. S. White, "	The S. S. White Dental Engine.

BRONZE MEDAL.

596	J. B. Seeley, Philadelphia,	Trusses.

HONORABLE MENTION.

785	J. B. Seeley, Philadelphia,	Silk Elastic Surgical Bandages.
903	Geo. P. Pilling, "	Surgical and Dental Instruments

XV.—Drugs, Dye Stuffs and Chemicals.

SILVER MEDAL.

84	Rosengarten & Sons, Philadelphia,	Purity of Chemical Preparations.
123	Powers & Weightman, "	For Fine Display, General Excellence and Purity of their Com. Chemical Preparations.*
361	Penna. Salt M f g Co., "	Fine Display and Purity of Sodium Bi-Carbonate.
25	Joseph Wharton, Camden, N. J.,	Superiority of Nickel and Nickel Compounds.
58	Mellor & Rittenhouse, Philadelphia,	Licorice.
24	Chas. Lippincott & Co., "	Soda Water Fountains.

BRONZE MEDAL.

1520	J. S. & T. Elkinton, Philadelphia,	Silicate of Soda.
256	Henry Bower, "	Excellence of Glycerine and other Chemicals.
352	J. M. Sharpless & Co., "	Purity of Dye Stuffs & Dye Woods.
357	Kurlbaum & Co., "	Purity and Beauty of Chemical Prep.
1333	Wm. Gulager, Philadelphia, for New England Glass Co., M'f'rs, Boston, Mass.,	Superior Glass Makers Litharge.

HONORABLE MENTION.

808	Wm. Gulager, Philadelphia, for Hartman Laist & Co., M'f'rs, Cincinnati, O.,	Excellent qualities of Glycerine.
1213	Harrison Bros. & Co., Philadelphia,	Excellence of Oil of Vitriol.
1369	Wm. B. Burke & Co., "	Hand and Machine-made Corks.
1123	McIlvaine & Bros., "	Uniformity of pulverization of Drugs and Spices.
585	Hansell & Bros., "	Apple Vinegar.
386	J. C. Hurst & Son, "	Burdict's Oil Polish Blacking.

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* Referred to Committee on Science and the Arts, with a recommendation to award the Elliot Cresson Gold Medal.

XVI.—Fine Arts and Photography.

SILVER MEDAL.

1486	F. Gutekunst, Philadelphia,	Glacé Photographs.
64	" " "	Large Plain Photographs.
383	Broadbent & Phillips, Philadelphia,	Large Crayon Photographs.
1004	Trask & Bacon, "	Plain Cabinet Pictures.
663	A. H. Hemple, "	L'ge Photo's of Engines & Machinery
572	Wm. G. Entriken, "	Oscillating Enameller for burnishing Photographs.
568	Jno. Carbutt, Sup't American Photo-Relief Printing Co., Philadelphia,	For Excellence in Lantern Slides and the Pictures of Bone, Tissue, Machinery, etc., by Woodbury Type Process.
1056	New York & Boston Sand Blast Co., Gorham Blake, Agent,	Tilghman's Etching Process on Glass.
846	Samuel Sartain, Philadelphia,	Steel Engravings.
182	Jas. R. Osgood & Co., Boston, Mass.,	Heliotypes—an Improved Method of Photo-Mechanical Printing.
698	Jas. W. Lauderbach, Philadelphia,	Wood Engraving.
570	Breuker & Kessler, "	Lithographed Bonds, etc.
818	Thos. Hunter, "	Chromos.
1519	Jas. S. Earle & Sons, "	Display of Rogers' Statuette Groups.
439	Potsdamer & Co., "	Lithographic Engraving.

BRONZE MEDAL.

1495	Broadbent & Phillips, Philadelphia,	Glacé Photographs.
557	Suddards & Fennimore, "	Large Colored Photographs.
647	James Cremer, "	Stereoscopic Views.
666	F. Langenheim, "	Col'd Albumen Magic Lantern Slides
114	Robert Steele, "	Illuminated Show Cards.
226	Louis Dreka, "	Stationery—Artistic Design & Workmanship.
385	Wells & Hope Co., "	Wells' Pat. Metallic Adv'ng Signs.
231	Mason & Co., "	Stationery—Artistic Design & Workmanship.
1149	Mrs. A. Pilkington, "	Wax Flowers and Preserved Geranium Leaves.
18	Janentzky & Co., "	Artists' Materials, Oil Colors, etc.
371	Estate of Thomas Heath, "	Plaster Statuary.
1068	Martha A. Torrey, "	Marking with Indelible Ink, Original Designs with Quill Pen.
1465	Geo. A. Rowe, "	Cameos and Intaglio Cuttings on Precious Stones, and Frame of Impressions in Wax.
915	Longacre & Co., "	Engraving on Wood.
19	Janentzky & Co., "	Water Colors.

HONORABLE MENTION.

1485	F. Gutekunst, Philadelphia,	Large Crayon Photographs.
122	P. E. Chillman & Co., Philadelphia,	Glacé Photographs.
275	Robt. Newell & Son, "	Acid proof Photo-Ware.
722	Benj. Linfoot, "	Architectural Water Color Drawing.
796	Crosscup & West, "	Wood Engraving of Machinery and Buildings.
281	Benerman & Wilson, "	Photographic Publications.
656	W. F. Geddes' Sons, "	Fruit and Can Labels in colors.

XVII.—Gents' Furnishing Goods, Canes and Umbrellas.

SILVER MEDAL.

155	Wm. A. Drown & Co., Philadelphia,	Umbrellas.
377	Ridgway & Oliphant, Philadelphia,	Gloves and Gauntlets.

BRONZE MEDAL.

1461	J. Herzberg & Bro., Philadelphia,	Patent Notch on Umbrella Frames.

HONORABLE MENTION.

163	Wanamaker & Brown, Philadelphia,	Clothing.
223	E. O. Thompson, "	Pantaloons and other Garments.
621	Richard Eyre, "	Shirts.
178	Carpenter & Latimer, "	Shirts.
325	Shedaker & Lindsey, "	Shirts.
255	F. Sachse & Son, "	Shirts.

XVIII.—Gold and Silver Ware, Plated Ware and Jewelry.

SILVER MEDAL.

157	Hastings & Co., Philade'phia,	Gold and Silver Leaf and Gold Foil.
202	Louis H. Spellier, Doylestown, Pa.	Clock, and Improvements therein.
1259	Hietel Bros., Philadelphia,	Improvement in Watch movements.

BRONZE MEDAL.

1226	Jas. E. Caldwell & Co., Philadelphia,	Jewelry and Silver Ware.
1343	Isaac Bedicheimer, "	Jewels and Emblems in Gold, Silver and Enamel.
1355	Madame K. Schmidt, Philadelphia,	Hair Jewelry.

HONORABLE MENTION.

924	Young & McCully, Philadelphia,	Masonic Marks and Jewel Settings.

XIX.—Hardware, Cutlery, &c.

SILVER MEDAL.

36	Hoopes & Townsend, Philadelphia	Bolts, Washers and Wood Screws.
99	McCaffrey & Bro., Philadelphia.	Files, Rasps, &c.
199	Stuart, Peterson & Co., Philadelphia,	Enameled and Tinned Cast Iron, Hollow Ware.
225	Howard W. Shipley, Philadelphia,	Pocket Cutlery.
870	J. B. Shannon, "	Builders' Hardware.
438	Russell & Erwin, M'fg Co., Phila.	Builders' Bronze Hardware.
126	Andrew Rankin, "	Bronze Metal & Hand-plated Goods.
17	Yale Lock M'fg Co. Stamford, Conn.	Store-door, Cabinet Locks & Latches.
1085	Mallory, Wheeler & Co., Field & Hardie, Agents,	Mortise, Rim and Padlocks.
747	Wm. Baldwin, Philadelphia,	Steel Forging Hammers, Sledges, &c.
471	Henry Disston & Sons, "	Saws and Tools.
1147	Charles Parker, Meriden, Conn.	Bench Vise.
618	Enterprise Manuf. Co., Philadelphia,	Coffee Mills.
1507	" " " "	Spice and Drug Mills.
212	A. B. Shipley & Son, "	Fishing Tackle.
65	L. Herder & Son, "	Shears and Scissors.

BRONZE MEDAL.

667	Alex. Krumbhaar, Philadelphia,	Files.
421	Washburn & Moen M'fg Co., N. Y. City,	Manufacturers' Wire.
422	White & Sansom, Philadelphia,	Table Cutlery.
735	Barrows, Savery & Co., Philadelphia,	Tailors'. Hatters' and Sad Irons.
1365	Wm. Ruoff. Philadelphia,	Patent Jackscrew.
47	Stevens Pat. Parallel Vise Co., New York,	Parallel Vises.
503	Hopkins & Dickerson, Field & Hardie, Ag'ts.	Bronze Door Knobs.
768	John P Verree & Co., Philadelphia, A. B Shipley & Son, Agents,	Hatchets.
453	Knickerbocker Ice Co, Philadelphia.	Ice Tools.

HONORABLE MENTION.

148	Hillebrand & Wolf, Philadelphia,	Trunk Locks and Padlocks.
872	E. S. Wells, "	Spoon-pointed Wood Screw.
1350	Philada. Tool Co., "	Davis' Patent Duplex Wrench.
763	John Booth & Sons, "	Brace-bits and Screwdrivers.
203	Wm. P. Walters' Sons, "	Mechanics' Tools.
1380	H. S. Tarr & Son, "	Excelsior Dry Level,
502	Field & Hardie, "	Window Pulley.
630	Baylis & Darby Manufac'g Co. Philada.	Wire Work.
772	Lloyd, Supplee & Walton, "	Bonney's Pat. Hollow Auger.
605	Heaton & Denckla, Agents Philadelphia, Union M'fg Co., New Britain Conn.	Plain and Fancy Door Butts.

XX.—Hats, Caps, and Furs.

BRONZE MEDAL.

544	F. K. Womrath,	Ladies Furs.

HONORABLE MENTION.

1006	W. H. Oakford, Philadelphia,	Hats.
810	Jno. A. Stambach & Co., Philadelphia.	Fancy Furs.

XXI.—House Building Materials, Tiles, and Terra Cotta Ware.

BRONZE MEDAL.

46	Wm. L. Wilson, Philadelphia,	Drain Pipe and Chimney Tops.
401	Fredk. Gossin, "	Garden Statuary and Vases.
97	Phila. Architectural Iron Co., Philad'a,	Galvanized Iron Work.
35	Austin & Obdyke, "	Corrugated Water Conductor.

HONORABLE MENTION.

196	Drury & Melluish, Philadelphia.	Plaster Ornaments.
1223	C. Burnham & Co., "	Gilroy's Weather Strips.
1138	McNeil, Irving & Rich, Elwood N. J.,	Pat. Waterproof Building Paper.
1210	Jos. E. Billings, Boston, Mass.,	Universal Angle Brick.
142	Geo. Hayes N. Y.	Hayes' Patent Skylight.
362	Wm. F. Scheible, Philadelphia.	Awnings and Decorations.

XXII.—Housekeeping Articles.

SILVER MEDAL.

145	C. G. Blatchley, Philadelphia,	Tingley's Patent Horizontal Ice Cream Freezer.
531	Wm. Wiler, "	Stair Rods.
347	John Gravenstine, "	Sideboard Refrigerator and Water Cooler Combined.

BRONZE MEDAL.

234	Chas. W. Packer, Philadelphia,	Ice Cream Freezer.
346	John Gravenstine, "	Refrigerator and Cooler Combined.
1197	Jeremiah Rohrer, Lancaster, Pa.,	"Iceberg" Refrigerator.
732	Barrows, Savery & Co., Philadelphia,	Refrigerator and Cooler Combined.
279	A. & R. O. Applegate, "	Centennial Ironing Table.
1100	E. S. Farson & Co., "	Schooley's Patent Self-Ventilating Refrigerator.
843	L. B. Justice, "	Seamen's Ice Cream Freezer.

HONORABLE MENTION.

1518	F. G. Ford, Philadelphia,	Pat. Coal Hod or Flour Pail and Sifter Combined.
578	Wilson, Wood & Co.. Wilmington, Del.,	Crockery Well Water Cooler.
1010	F. Lawrence, Philadelphia,	Revolving Flower Bracket.
435	Orum & Millor, "	Gas Bracket Match Safe.
333	Amanda S. Sherwood, Philadelphia,	Bixler's Fountain Griddle Greaser.
934	Thos. Mills & Bro., "	Steam Engine and Ice Cream Freezer Combined.
1361	John McConn, "	Non-Explosive Steam Coffee Pot.
1388	T. B. Hagner, "	American Automatic Filterers.

XXIII.—India-Rubber Goods.

SILVER MEDAL.

1409	A. K. Young & Conant Manufacturing Co., Boston, Mass.,	Gossamer Waterproof Garments.

HONORABLE MENTION.

1095	New York Belting and Packing Co., D. P. Dieterich Agent, Philadelphia.	Rubber Belting.
216	Boston Elastic Fabric Co., Potter & Hoffman, Agents, Philadelphia,	Rubber Fire Hose.

XXIV.—Iron and Steel.

SILVER MEDAL.

716	Alan Wood & Co., Philadelphia,	Patent Planished Sheet Iron.
1324	Am. Tubular Iron and Steel Asso., Phila.,	Wheeler's Tubular Wrought Iron.
606	Midvale Steel Works, Nicetown, Pa.,	Crucible Cast Steel.
607	" " " "	Steel made by Siemen's Martin process.
27	Phila. Galvanizing Co., Philadelphia,	Galvanized Iron.
1367	Pennsylvania Combined Iron and Steel Association, Philadelphia,	Wheeler's Combined Iron and Steel for Railroad and Merchant Bars.
822	Susquehanna Iron Co., Columbia, Pa.,	Merchant Bar Iron.
956	Fitzgerald, Flagg & Co., Philadelphia,	Cast Steel Castings.

BRONZE MEDAL.

407	Phila. Hydraulic Works, "	McHaffie Direct Steel Castings.
312	Hanson & Kirk, "	Cemetery-Lot Enclosings.
215	Union Iron Co., Buffalo, N. Y., Potter & Hoffman, Agents, Philadelphia,	Long Iron Beams.
355	Miller, Barr & Parkin, Pittsburg, Pa.,	Cast Steel.
1303	Goodell & Waters, Philadelphia,	Iron Castings.

HONORABLE MENTION.

1136	Malin Bro's. Philadelphia,	Pig Iron.
1330	Edw'd J. Etting, "	Allentown Iron Co.'s Pig Iron.
337	Chas. H. Kellogg, " Potter & Hoffman, Agents,	Wrought Iron Column.

XXV.—Ladies' Fancy Goods.

SILVER MEDAL.

91	Birge & Berg, Philadelphia,	Artificial Flowers.
441	M. Shoemaker & Co., Philadelphia,	Children's Clothing.
468	Ladies' Depositary, "	Fancy and Useful Articles.
1456	Mrs. M. E. B. Wynne, New York,	Fancy Stitching on Shoes.
1464	Miss Maggie M. Doran, Philadelphia,	Glove Making.

BRONZE MEDAL.

380	Mrs. E. Keyser, Philadelphia,	Children's Clothing.
1268	A. J. Iander, "	Afghan and Needlework.
1368	W. B. Moore, "	Tips and Tags for Lacings.

HONORABLE MENTION.

294	Wm. Brooks, Philadelphia,	Bonnets.
373	Davjd Wood, "	Infant's Clothing.
1281	Wheeler & Wilson Mfg. Co., Philadelphia,	Samples of Stitching.

XXVI.—Gas Fixtures.

SILVER MEDAL.

100	Cornelius & Sons, Philadelphia,	Gas Fixtures.
501	M. B. Dyott & Son, "	Champion Street Lamps.

BRONZE MEDAL.

83	Baker, Arnold & Co., Philadelphia,	Gas Fixtures.
777	Wilhelm & Neuman, "	Street Lamps.
1018	August Wilhelm, "	Ceiling Reflector.

HONORABLE MENTION.

109	American Reflector Co., Philadelphia,	Goetz' Day and Gas Light Reflectors.

XXVII.—Leather and Morocco.

SILVER MEDAL.

1445	F. Braun, Philadelphia,	Calf Skins.

BRONZE MEDAL.

191	Eckfeldt & Richie, Philadelphia,	Oak-Tanned Butts for Hose & Belting.

HONORABLE MENTION.

2.1	A. McKnight & Co., Philadelphia,	Waterproof Leather.
276	Ed'd Spaulding, Boston, Mass.,	Hemlock-Tanned Sole Leather.
434	Deitrich & Whittington, Philadelphia,	Meyer's Pat. Marbled Sheep Skins.
764	C. B. Williams' Sons, "	Oak-Tanned Sole Leather.

XXVIII.—Marble, Stone, etc.

BRONZE MEDAL.

396	Adam Steinmetz, Philadelphia,	Colored American Marble Mantels.
1168	Wm. R. Hanson & Son, "	Lake Champlain Colored Marbles.
244	Chas. Williams, "	Marbleized Slate Mantels.
303	Wilson & Miller, "	" " "
321	Hayes, Coulter & Co., "	" " "
40	J. B. Kimes & Co., "	" " "
677	Thompson & Harper, "	" " "
130	J. E. Mitchell,	Collection of Grindstones, Oilstones, Curriers' Blocks and French Burr Millstones.

XXIX.-1.—Generators of Power.

SILVER MEDAL.

853	Harrison Boiler Works, Philadelphia.	Harrison's Sectional Boiler.

BRONZE MEDAL.

710	Steam Generator Mf'g Co., Philadelphia.	The Wiegand Sectional Safety Steam Generator.
690	Wm. J. Connery, "	Connery's Concave Caulking.
1084	Wm. T. Bates, Conshohocken, Pa.	Feed Water Heater and Filter.
287	Henry Snyder & Co., Philadelphia,	Shapley Steam-Engine, Portable.

HONORABLE MENTION.

627	Norris Iron Co., Norristown, Pa.	Norris Iron Co.'s Improvements on Rogers & Black's Boilers.
511	Waters' Pat. Heater Co., W. Meriden, Conn.	Waters' Pat. Feed Water Heater.

XXIX–2.—Motors other than Water-Wheels.

BRONZE MEDAL.

101	Robert Wetherill, Chester, Pa.,	Corliss Steam-Engine.
158	Andrew Watson, Philadelphia,	Upright Steam-Engine.
389	Jacob Naylor, "	Horizontal Steam-Engine.
457	Wilbraham & Bro., "	Horizontal Steam-Engine.

HONORABLE MENTION.

495	Shive Governor Co., Bethlehem, Pa.,	Shive Steam-Engine Governor.
553	Jacob Naylor, Philadelphia,	Balance Slide-Valve.
390	Jacob Naylor, "	Vertical Steam-Engines, 6 in., 8 in., 10 in. and 12 in. Cylinders.
636	Jenkins & Lee, "	Marine Governors.
551	Richards & Pike, "	Barr's Eliptic Steam Trap.
392	J. T. Mecutchen, "	Patent Eccentric Hook.

XXIX–3.—Machinery of Transmission.

SILVER MEDAL.

12	Alexander Bros., Philadelphia,	Leather Belting.
800	James Eccles, "	Model of Patent Pivot Centre for Drawbridge.
153	T. J. Rorer, "	Combination Union Belt.

BRONZE MEDAL.

177	Geo. V. Cresson, Philadelphia,	Internal Clamp Coupling for Shaft'g.
183	Sellers Bros., "	Main Driving Belt. J. B. Hoyt & Co., M'f'rs, New York.
1439	Pusey, Jones & Co., Wilmington,	Expanding Pulleys.
1440	" " " "	Wire Guide.

HONORABLE MENTION.

170	Murray Bacon, Philadelphia,	Rotary Circulating Fan.
141	Geo. V. Cresson, "	Shafting Hangers and Pulleys.
306	Wright & Smith, Machine W'ks, Newark, New Jersey,	Variable Speed Shafting.
574	James F. Tygh, Philadelphia,	Cigar Shield, Self Pressing.
514	Wm. M. Smith, Philadelphia.	Device for Driving Sewing Machines with Variable Speed.

XXIX–4.—Machinery of Transportation.

SILVER MEDAL.

7	The Wharton R. R. Switch Co., Phila.,	Wharton's Safety Railroad Switch.
648	*B. Tatham & J. W. Brittin, New York City,	Safety Catch for Elevators.

BRONZE MEDAL.

629	Gec. J. Woodruff, Norristown, Pa.,	Model of Railroad Switch.
310	Nichols, Pickering & Co., Philadelphia,	Elliptic, Nest, Spiral and Volute Springs.
586	Stokes & Parrish, Philadelphia,	Elevator Winding Engine.
774	J. G. Brill & Co., "	Street Car Starter.
1230	Sellers Bros., "	Wrought Iron Bridge Railing.
583	C. W. Hunt, New York City,	Automatic Railway.
584	" " " "	Automatic Elevator.

* Referred to Committee of Science and the Arts. With a recommendation for the higher awards of the Institute.

HONORABLE MENTION.

6	Wm. Wharton, Jr., Philadelphia,	Rail Curving Machine.
9	The Wharton R. R. Switch Co., Phila.,	Steel Railroad Frog.
260	Thos. McBride, Philadelphia,	Hydraulic Car Brake.
1272	J. Singer & R. Mench, Harrisburg, Pa.,	Singer's Pat. Autom'ic Car Coupler.
1146	C. D. Alexander, Philadelphia,	McConnell's Automatic Car Coupler.
1271	Jacob Singer, Harrisburg, Pa.,	McAllister's Imp'd R. R. Brake Shoe.
382	Davis & Foulke, Philadelphia,	Fitts' American Road Steamer.

XXIX–5.—*Pumps, Hydrants, etc.*

BRONZE MEDAL.

106	R. D. Wood & Co., Philadelphia,	Mathew's Patent Fire Hydrant.
247	E. L. Richie, "	Slouthron's Bilge and Force Pump.
263	Rue Manufacturing Co. "	Little Giant Injector.

HONORABLE MENTION.

693	R. T. H. Stileman, Philadelphia,	Stop Cocks and Valves.
113	Cooper, Jones & Cadbury, "	Excelsior Suction and Force Pump.
632	J. H. Billington & Co., "	Putnam's People's Pump.
967	F. B. Colton, "	Prall's Pat. Aquameter Steam Pump.
446	Ferrell & Jones, "	Steam Pump.
1161	*Thos. M. Shank,	Water Meter.

XXIX–6.—*Machine Tools.*

SILVER MEDAL.

1513	Northampton Emery Wheel Co., Leeds, Mass., W. P. Walters' Sons, Agents,	Stove Plate Emery Wheel Grinding Machine.
105	Adam Neukumet, Philadelphia,	Keystone Crucible Machine.
129	J. Henry Mitchell, Philadelphia,	Iron Boxes & Grindstone Fixtures.
363	Oberlin Smith & Bro., Bridgeton, N. J.	Can Makers, Presses and Dies.
444	Thorne, De Haven & Co., Philadelphia,	Portable Drilling Machine.
448	Kiehner & Odenatt, "	Valve Seat & Metal-planing Machine.
449	C. Van Haagen & Co., "	Rotary Shaper.
533	Packer & Bates, "	Machine for Oval & Circular Cutting.
912	Henry Snyder & Co., "	Ames Engine Lathe.
1082	E. & A. Betts, Wilmington, Del.	Reder's Pat. Adjustment for Lathe Tool-posts.
217	P. H. & T. N. Root; Potter & Hoffman, Agents, Philadelphia,	Portable Forge.
458	T. Wilbraham & Bros., Philadelphia,	Baker's Pressure Blower.
1127	John L. Mason, "	Tire Shrinker.
21	Pliny E. Chase, Newark N. J.	Foot Back Geared Slide Lathes.
169	Murray Bacon, Philadelphia,	Hand Lathes.
1233	The Tanite Co., Stroudsburg, Pa.	Emery Wheel Milling Machine.
1494	D. P Dieterich, Philadelphia,	Vulcanite Emery Wheels.
1481	C. Van Haagen & Co., Philadelphia,	Twist Drill Grinding Machine.
761	Ferris & Miles, "	Axle Lathe.

BRONZE MEDAL.

75	Keystone Portable Forge Co., Philada.	Baxter Portable Forges.
98	Northampton Emery Wheel Co., Leeds, Mass., W. P. Walters' Sons, Agents,	Emery Wheels.
345	John Bird, Philadelphia,	Press for moulding Glassware.
575	James F. Tygh, Philadelphia,	Tobacco Strip'g & Booking Machine.

*Referred to Committee on Sciences and the Arts for Examination.

BRONZE MEDAL.

1183	Lucien B. Flanders, Philadelphia,	Pat. Portable Cylinder Boring Machine.
968	Charles Crossley, Philadelphia,	Patent Mill Picks.
1024	Allison & Bannan, Port Carbon, Pa.	Allison's Patent Boring Machine.
1237	Isaac H. Shearman, Philadelphia,	Johnson's Lathe Chuck.
1192	T. R. Evans, "	Indexical Revolving Boot and Shoe-tree Stretcher.
1239	Hill, Clark & Co., Boston, Mass.	No. 3 Brainerd Miller.
1295	W. D. Chase, M'fg Co., New York.	Chase's Pipe Cutting Machine.
1311	Keystone Portable Forge Co. Philada.	Grimes' Pressure Blower.

HONORABLE MENTION.

228	Lehigh Valley Emery Wheel Co., Weissport, Pa.	Butterfields Emery Wheels & Grinder.
1514	Chas. M. Chriskey, Philadelphia,	Portable Forges.
1047	George Richards, "	Twist Drill Grinding Machine.
1238	R. L. Howard & Son, Buffalo, N. Y.	6-inch Schlinker Bolt Cutter.
1241	Wood Light Machine Co., Worcester, Mass.	No. 1. Bolt Cutter.
1240	Hill, Clark & Co., Boston, Mass.	Index Miller.
1498	The Tanite Co., Stroudsbury, Pa.,	Emery Wheels,
1256	C. J. Gardner, Philadelphia,	Saw Grinding Machine. (Model.)
424 425 426	E. & A. Betts, Wilmington, Del.,	Display of Machine Tools.

XXIX–7.—Wood-Working Machinery.

SILVER MEDAL.

540	D. J. Lattimore, Philadelphia,	McClelland's Planing Mach. Duster.
593	Goodell, Braun & Waters, Philadelphia,	Endless Bed, Double Surfacer and Matcher.
594	" " "	Heavy Bar Mortiser and Borer.
1490	Power, Tainter & Co., "	Re-Sawing Machine.

BRONZE MEDAL.

300	Trump Brothers, Wilmington, Del.	Fleetwood Scroll Saw.
307	Power, Tainter & Co, Philadelphia,	Woodward Double Surfacing Floor-Board Planing Machine.

HONORABLE MENTION.

494	R. McChesney, Ilion, N. Y.	Truss Arm Scroll Saw.
1054	Walker Bros., Minneapolis, Minn.	Scroll Saw.
1145	J. H. Blaisdell & Co., Philadelphia,	Sash Boring and Grooving Machine.
1436	James M. Seymour, Newark, N. J.	Sash Dovetailing Machine.
1491	Power, Tainter & Co., Philadelphia,	Combined Sash Sticking and Moulding Machine.

XXIX–8—Textile Machinery.

SILVER MEDAL.

41	H. W. Butterworth & Sons, Philadelphia,	Warp and Cloth Drying Machine.
1397	Thos. Wood, Philadelphia,	8-Box Power Loom.
545	Dienelt & Eisenhardt, Philadelphia,	W. V. Gee's Pat. P'wr Carpet Loom.
1441	Pusey, Jones & Co,, Wilmington, Del.	Rag Cutter.
180	Thomas Wood, Philadelphia,	Single Box Power Loom.

BRONZE MEDAL.

826	Wm. McArthur & Co., Philadelphia,	McArthur's Patent Steam Feather Renovator.

HONORABLE MENTION.

1398	Thomas Wood, Philadelphia.	Winding Machine.
827	W. McArthur & Co., Philadelphia.	Steam & Hot Air Carpet Cleaning Machine.

XXIX–9.—*Sewing Machines.*

SILVER MEDAL.

28	Cutlan Shoe S M. Co., Philadelphia,	Cutlan Shoe Machine.
324	George C. Walters, Philadelphia,	Wet Skin Sewing Machine.
118	Rex & Bockius, "	Goodes Sewing Machine.

BRONZE MEDAL.

418	A. B. Felt & Co., Philadelphia,	Vertical Feed applied to the Davis Sewing Machine.
313	Cyrus S. Cushman, "	Sewing Machine Attachment.
397	John Mundell & Co., "	Machine for Screwing Soles on Boots and Shoes.
1489	A. C. McKnight, Philadelphia, for Cable Screw Co., Boston, Mass.	American Cable Screw Wire Machine for Boots and Shoes.

HONORABLE MENTION.

1086	Jos. J. West, New York,	Duplex Braiding and Embroidering Attachment.
437	Adjustable Table Co., Philadelphia,	Adjustable S. M. Table.
1342	J. Thomas Jones, Ilion, N. Y.,	"Eureka." The Remington Anatomical Treadle for Sewing Machines.

XXIX–10.—*Laundry Machinery.*

BRONZE MEDAL.

251	American Machine Co., Philadelphia,	Crown Clothes Wringer.
537	James Bing, Philadelphia,	R. A. Stratton's Mangle or Calender.
368	R. H. Farley "	Champion Steam Washer.

HONORABLE MENTION.

1202	J. D. Brick, Philadelphia,	Electric Washing Machine.

XXIX.–11.—*Paper Machinery.*

SILVER MEDAL.

195	Brown & Carver, Philadelphia,	Paper Cutting Machine.
1048	Brown & Carver, "	Hand Paper Cutter.
384	R. Mohler, "	Fourdrinier Wire Cloth.
1228	Sellers Brothers, "	Whitehead's Dandy Roll.
1232	Sellers Brothers, "	Paper Maker's Cylinder.
427	Nelson Gavit, "	Pat. Cone Pully Paper Cutter.
50	*Chambers Brothers, "	Fast Rotary News Folder.
51	* " " "	16 Page Folder and Paster.
52	* " " "	Adjustable 8 vo. and 12 mo. Book Folder.
406	*J. Morton Poole & Co., Wilmington, Del.,	Machine Calender Rolls.

BRONZE MEDAL.

11	Charles J. Cohen, Philadelphia, for Allen's Manufacturing Co. Norwich, Conn,	Allen's Machine for Gumming and Folding Envelopes.
298	R. S. Menamin, Philadelphia,	Heston's Label Cutter.

HONORABLE MENTION.

171	Wm. H. Burkhardt & Co., Philadelphia,	Cedar Ship Tank.
172	George J. Burkhardt & Co., "	Square and Round Cedar Tank.
480	Sellers Brothers, "	Paper Makers Fourdrinier Wire Cloth.
1164	Nelson Gavit, Philadelphia,	Paper Testing Machine.

* All of Chambers Brothers & Co's Machines are referred to the Committee of Science and the Arts for still higher awards. J. Morton Poole & Co., also referred to the Committee of Science and the Arts for still higher awards.

XXIX.—12.—*Rope Machinery.*

No Exhibits.

XXIX.—13.—*Sugar Machinery and Chemical Appliances.*

SILVER MEDAL.

162	Henry G. Morris, Philadelphia,	Improvements on D. M. Weston's Centrifugal Machines.
484	Walker Brothers & Co., Philadelphia,	Lightning Mill.
1431	Greene & Platt, "	Improved Fire Extinguisher.
76	David Stewart, "	Cracker Machine.

BRONZE MEDAL.

1468	George J. Burkhardt & Co., Philadelphia,	Improved Scotch Mashing Machine.
930	Thos. Mills & Brother, "	Excelsior Candy Toy Machine.
932	Thos. Mills & Brother, "	Improved Cocoa Nut Grating M'chn.
933	Thos. Mills & Brother, "	Fruit Drop Machine.

HONORABLE MENTION.

488	Walker Brothers, Philadelphia,	Farm Mill.
342	Kreider, Zindgraft & Co., Philadelphia,	Thompson's 30 inch Patent Portable French Burr Grain Mill.
343	Kreider, Zindgraft & Co., Philadelphia,	Thompson's 24 inch Patent Paint Mill, with Mixer.
55	Baugh & Sons, Philadelphia,	E. P. Baugh's Patent Sectional Mills.
179	W. H. and S. A. Slocomb, Philadelphia,	Fruit Cleaner, Apple Parer and Corer combined.
1469	Geo. J. Burkhardt & Co., Philadelphia,	Grains Valves.
26	Phila. Fire Extinguishing Co. "	Gardner's Triumph Hook and Ladder Truck.
684	C. K. Bullock, Philadelphia,	Straub Portable Grain Mill.

XXIX–14.—*Stone Machinery.*

SILVER MEDAL,

417	Excelsior Brick and Stone Co. Philadel.	Gregg's Excelsior Brick Making Machine.
562	Penna. Diamond Drill Co., Pottsville, Pa.,	Diamond Pointed Steam Drill.

BRONZE MEDAL.

582	Samuel P. Miller & Son, Philadelphia,	Hand Brick Press.

HONORABLE MENTION.

53	Chambers Bros. & Co., Philadelphia.	Brick Machine.

XXIX–15.—*Gas Machinery.*

SILVER MEDAL.

1521	American Meter Co., Philadelphia.	Improved jet Photometers (conditional award.)

BRONZE MEDAL.

1143	American Meter Co., Philadelphia,	Hopper's Dry Gas Meter.
161	Henry G. Morris, "	Self-Sealing Retort Lids.

HONORABLE MENTION.

1511	Harris, Griffin & Co., Philadelphia,	Dry Gas Meter.
472	Collins & Curl, Philadelphia,	Lacy's Automatic Gas Saver.
916	Samuel H. Mervine, Jr., Philadelphia.	Gas Regulator and Four way Stop Cock.

XXIX–16.—*Lubricating Oils and Engineering Supplies.*

SILVER MEDAL.

466	John W. Tully, Philadelphia,	Paint Filler for Wood and Metal.

BRONZE MEDAL.

487	E. F. Houghton & Co., Philadelphia,	Cosmo-lubric Oil.
658	Morehouse, Rockafeller & Co., Philad'a,	Paraffine Oil.
657	Eclipse Lubricating Oil Co., Franklin, Pa.,	Tweddle's Improvements in Manufacturing Mineral Oil.
1321	Taber, Harbert & Co., Philadelphia,	Monument No. 1 Illuminating Oil.
1180	Wm. L. Elkins, "	Continental Burning Oil.
1178	" " "	Belmont Burning Oil.
1474	" " "	Head-Light Oil, 175 degrees.
564	Davis & Dubois, "	Combination Tallow Cup.
791	Wickersham & Bro., "	The Wickersham Oil Cup.

HONORABLE MENTION.

1339	Crew, Moore & Levick, Philadelphia,	General Display of Oils.
1378	Geo. J. Faller, "	Excelsior Sewing Machine Oil.
863	Shepherd & Lloyd, Philadelphia, Agents for Tubular Barrow and Truck Co., Jersey City, N. J.,	Tubular Iron Wheelbarrow,
290	Edw'd Brown, Philadelphia,	Revolution Indicator.
865	Chas. Parham, "	Fine Machine Screws.
786	B. E. Lehman, Bethlehem, Pa.,	Ross' Patent Gauge Cock.
1039	Jos. Heginbothom, Philadelphia,	Swann's Patent Safety Valve.
955	Geo. Sumner, "	Steam Regulating Valve.
419	Chapman Valve Mfg. Co., Boston, Mass.,	Chapman Valve.
977	E. Schmidt, Philadelphia.	Steam Guage.
1301	E. H. Ashcroft, Boston, Mass.	Pop Safety Valve, nickel seated.
1286	E. H. Ashcroft, " "	Self-Testing Steam Guage.

XXX.—Musical Instruments.

SILVER MEDAL.

769	Wm. F. Seefeldt, Philadelphia,	Quartette of Brass Instruments.

BRONZE MEDAL.

66	Schomacker Piano Mfg. Co., Philadelphia,	Square Piano, No. 10,391.
1314	A. B. Felt & Co., Philadelphia, for Horace Waters & Son, Mfrs., New York,	Cabinet (reed) Organ, No. 31,960.
641	Jno. Albert, Philadelphia,	Stringed Instruments.

HONORABLE MENTION.

236	Albert Schoenhut, Philadelphia,	Toy Piano and Mellophone.
778	Rosewig & Stoll, Philadelphia, for A. M. McPhail & Co., Mfrs., Boston,	Square Piano, No. 11,136.
402	Prestien & Berwind, Philadelphia,	Square Piano, No. 702.
354	Albrecht & Co., "	Square Piano, No. 1265.

XXXI.—Paints, Colors, Varnishes, Etc.

SILVER MEDAL.

965	Harrison Bro's & Co., Philadelphia,	Case of Colors.
1155	L. Martin & Co., "	Lamp Black.

BRONZE MEDAL.

612	Bihn & Co., Philadelphia,	Lamp Black.

XXXII.—Paper Hangings.

SILVER MEDAL.

555	A. Goth & Co., Bethlehem, Pa.,	Oil Painted Wall Papers & Frescoes.

BRONZE MEDAL.

451	Howell & Bro's, Philadelphia,	Excellence in Cheap Paper Hangings.
554	Nagle, Cooke & Ewing, Philadelphia,	Fine Selection of Wall Papers and artistic taste in hanging.

XXXIII.—Philosophical, Optical and Mathematical Instruments.

SILVER MEDAL.

1152	Becker & Son, N. Y.	Balances of precision.
1235	D. R. Walker, Phila.,	Fire Alarm Telegraph.
1251	J. W. Queen & Co., Philadelphia,	Edgerton's Self-condensing gas Cyl'r.
482	*Joseph Zentmayer, Philadelphia,	Microscopes and Objectives.
969	L. J. Marcy, Philadelphia,	Sciopticon.
849	Albert G. Busby, Philadelphia,	Stereopticon.
1273	T. A. Wilson & Co., Reading, Pa.,	Arundel Tinted Spectacles.
1051	Galvano Faradic Mfg. Co., New York,	Galvano-therapeutic Apparatus.
365	Wm. G. A. Bonwill, Philadelphia,	Electro Magnetic Mallet.
1255	Am. District Telegraph Co., New Yo k,	Improved Burglar Alarm Apparatus.
127	Heller & Brightly, Philadelphia,	Surveying Instruments.
829	W. J. Young & Sons, Philadelphia,	Coast Surveying Instruments.
1254	J. W. Queen & Co., Philadelphia.	Eaton's direct vision Spectroscope.

BRONZE MEDAL.

1058	Caspar W. Briggs, Philadelphia.	Magic Lantern Slides.
600	Thos. E. Cornish, "	House and Hotel Annunciators.
1204	Wm. J. Phillips, "	Printing Telegraph Instrument.
497	Shive Governor Co., Bethlehem, Pa.,	Shive's Watchman's Clock.

HONORABLE MENTION.

369	J. B. Shannon, Philadelphia,	Electro Mag. Annunciator for Hotels.
1206	Wm. Hockhauser, New York,	Morse Tel. Register, (self-starting.)

1174	I. P. Fries, Relay Switch Founder,	Referred to the Committee on Science and the Arts for Exam'n.
1284	E. T. Phillips' Pat. Cov'd Telegraph Wire,	
1410	Thurston's Testing Machine,	

XXXIV.—Printing and Typography.

SILVER MEDAL.

659	Jno. T. Graham & Co., Philadelphia,	Sholes & Glidden "Type Writer."
463	†Bullock Printing Press Co., Philada.,	Bullock Printing Press. Built by I. P. Morris & Co.
1094	E. Haughwout & Co., New York City,	Universal Printing Press.

BRONZE MEDAL.

1515	Taylor & Smith, Philadelphia,	Engraving and Printing Color Blocks
206	Robert S. Menamin, Philadelphia,	Lawrence's Pat. Brass Galley.
297	" " "	Bronstrup Lithographic Press.
1427	Mellor & Rittenhouse, "	Printer's Composition Rollers.
508	Rex & Bockius, "	Goodes' Gem Self-Ink. Print. Press.
176	Taylor & Smith, "	Photo-Lithographing.
372	Graf Bros., "	Imprv'd Autographic Transferable Ink.

* Referred to the Committee on Science and the Arts, with the recommendation of the Elliot Cresson Gold Medal.

† Bullock Printing Press referred to Committee on Science and the Arts, with a recommendation of the Elliott Cresson Gold Medal.

HONORABLE MENTION.

295	Robt. S. Menamin, Philadelphia,		Printer's Chases.
329	Times Printing House, Philadelphia,		Specimen of Ornamental Letter Press Printing.
910	J. W. Daughaday & Co,,	"	Small hand Printing Press.
1244	Rowley & Chew,	"	Specimens of Wood Block Printing.
1450	Samuel P. Ferree,	"	Specimens of Printing from 5 color Chromo type Cyl. Printing Presses.

XXXV.—Saddlery, Harness, Trunks and Whips.

SILVER MEDAL.

804	A. S. Jenks, Philadelphia,		Hines' Pat. Driving Bit.

HONORABLE MENTION.

566	Samuel R. Phillips, Philadelphia,		Harness (Double and Single.)
579	Watt & Kennedy,	"	Trunks for Mercantile and other purposes.
102	S. H. Allen	"	Fine Harness Ornaments,
1419	A. Lynch,	"	Single and Double Harness.
1304	Boland Bros.	"	Wood Hames.

XXXVI.—Safes, Bank Locks and Scales.

SILVER MEDAL.

317	Fairbanks & Ewing, Philadelphia,		Railroad Track Scales.
318	" "	"	Hay or Coal Scales.
507	H. Troemner,	"	Fine Balances.
650	Farrel, Herring & Co.,	"	Franklinite backing in Burglar Proof Safes.
1267	Riehlè Bros.,	"	Charging Scales.

BRONZE MEDAL.

1191	Moore & Mixsell, Philadelphia, for Brandon Manufacturing Co.,		Knife Edges in Howe R. R. Track Scales.
1264	Riehlè Bros., Philadelphia,		Window Beam showing Graduation & Figures on top in wagon scales
1186	Moore & Mixsell,	"	New Arrangement for Drop Lever Scales.
905	W. Harmar Thomas,		Steam Safes.

HONORABLE MENTION.

200	Stewart, Marks, Ralph & Co., Phila.,		Packing and Weighing Machine.
1046	*Worrall Bank Lock Co., Philadelphia.,		Bank Lock.

XXXVII.—School Furniture and Educational Appliances.

SILVER MEDAL.

1037	J. A. Bancroft & Co., Philadelphia,		H. L. Andrews' Gothic School Desks and Seats.

HONORABLE MENTION.

409	John L. Smith, Phila delphia,		Map Case with Maps on Spr'g Rollers
107	John H. Harden,	"	Adjustable Drawing Board Trestle.
151	I. Newton Pierce,	"	Folding School Desk and Seat.

XXXVIII.—Soaps and Perfumery.

SILVER MEDAL.

954	McKeone, Van Haagen & Co., Philada.,		White Castile, Toilet and Laundry Soaps.
855	Arthur Fricke,	"	Perfumery.

*Referred to the Committee on Science and the Arts for examination.

BRONZE MEDAL.

1124	Wm. Conway, Philadelphia,	Laundry Soaps.
80	J. S. & T. Elkinton, "	Clarified Soap.
30	S. C. Upham, "	Centennial Bouquet Perfume.
582	Wm. Wrigley, "	Mineral Scouring Soap.
711	W. H. Savournin, "	Lilly White Toilet Powder and Rouge.

HONORABLE MENTION.

49	Samuel Campbell, Philadelphia,	Extract of Hyacinthine.

XXXIX.—Steam Heaters, Heaters, Ranges, and Ventilators.

SILVER MEDAL.

1042	J. Reynolds & Sons, Philadelphia,	Wrought Iron Furnace for setting in brick work.
364	McCoy & Roberts, Philadelphia,	Cold Case Hot Air Portable Heater.
1214	T. S. Dixon & Sons, "	Low Down and Elevated Grates, and Fenders.

BRONZE MEDAL.

1041	J. Reynolds & Sons, Philadelphia,	Centennial Hot Air Furnace.
71	D. Mershon's Sons, "	Air Tight Russian Heater.
37	Jno. McConn, "	Steam Radiator.
88	W. H. Harrison & Bro., "	Low Down and Elevated Grates, and Fenders.
1224	C. Burnham & Co., "	Reflecting Gas Stove.
1316	C. Gefrorer, "	Gas Heating Apparatus.
293	Strow, Wile & Co., "	Black Lead Crucibles.
744	Frank Lawrence, "	Patent Tuyere and Cupola.
135	Morris & Haines,	Portable Heater.
243	Charles Williams,	Heaters, Portable & set in brick work

HONORABLE MENTION.

509	J. P. Hayes & Bro., Philadelphia,	Rotary Hot Blast Portable Heater.
274	Leibrandt & McDowell Co., Philadelphia,	Victor Cooking Stove.
1225	C. Burnham & Co., "	Gas Cooking Stove.
913	G. Morgan Eldridge, "	Automatic Stove Damper.
1516	Strow, Wile & Co., "	Sunnyside Stove Polish.
1395	Adam Newkumet, "	Keystone Stove Polish.
798	J. W. Middleton, "	Automatic Regulator.
56	Geo. R. Barker, "	Combined Heating and Ventilating Apparatus.
89	W. H. Harrison & Bros.,	Warm Air Furnaces.

XL.—Miscellaneous.

SILVER MEDAL.

694	*Henry R. Heyl, Philadelphia,	Patent Wire-Fastened Paper Boxes.
525	H. H. Peacock, "	Inlaid Jewel Caskets.
233	Geo. F. Kolb, "	Morocco and Velvet Jewel Cases.
154	C. F. Rumpp, "	Fancy Leather Goods.

BRONZE MEDAL.

68	N. M. Kerr & Co., Philadelphia,	Paper Boxes for Jewelry, etc.
558	Chas. Rumpp, "	Fancy Leather Goods.

HONORABLE MENTION.

1453	Thos. Musgrove & Co., Philadelphia,	Patent Paper Boxes.
348	Edw'd Wattis, Jr., "	Patent Pocket Flasks.
830	Jacob Hoffman & Son, "	Pearl Handles, Studs, and Buttons.

* Referred to Committee on Sciences and the Arts, with the recommendation of the award of the Scott's Legacy Medal and Premium.

Civil and Mechanical Engineering.

COMPOUND AND NON-COMPOUND ENGINES.*

By Chas. E. Emery, C. E.

Messrs. Editors:—The experiments with the "Bache" form part of an extended series of investigations with steam machinery of various kinds, made to ascertain the best means of securing economy of fuel. The experiments were commenced by the writer (then an Assistant Engineer in the U. S. Navy) in the year 1866, and were continued in connection with the Novelty Iron Works, New York, where a special apparatus was fitted up for the purpose. [The experiments were entirely independent of those the Government had in progress at the same time.] Among other results it was in due time developed that the compound engine furnished one of the best practical means of securing economy of fuel, but the proprietors of the Novelty Iron Works decided to close the establishment in the winter of '69-'70, and nothing further was done at the time.

The results then obtained showed with considerable accuracy the law of variation in the cost of the power due to the changes of the steam pressure and degree of expansion, with other matter of importance, which, coming to the attention of Capt. C. P. Patterson, then connected with, now Superintendent of the U. S. Coast Survey, so interested him that he made arrangements to provide the means required to complete the trials on the plan originally intended. The experimental machinery was in part purchased in the general sale at the Novelty Works, and after being reconstructed the experiments were in due time proceeded with, though the loss of the skilled workmen and facilities of the Novelty Works was severely felt and caused unexpected expenses and delay. Messrs. Hecker & Bro., the well-known millers, with characteristic public spirit rendered valuable assistance by providing a location for the machinery, with use of boilers, pumps, etc.

These experiments included a trial of nearly every possible change of arrangement and condition to which simple and compound engines could be put in relation to steam pressure, expansion, use of steam jackets, etc. Upon completing the principal computations it was found desirable to ascertain the nature of the change in result due to increasing the size of engines of the same general character. Other experiments with which I had been associated furnished part of the necessary data, but to still further complete the investigation, with the consent of the Superintendent of the Coast Survey practical experiments were made with the machinery of the U. S. Coast Survey

* Report of Experiments made with the Steam Machinery of the U. S. Coast Survey Steamer "Bache," under the general direction of Charles E. Emery, Consulting Engineer. (Published by permission of the Superintendent of the U. S Coast Survey.)

Steamers "Blake" and "Bache" corresponding to some of those with the experimental apparatus.

The pressure of professional duties has prevented me from promptly completing the arrangement and discussion of the many hundred experiments with the deductions due to the numerous changes of condition, but the results will as soon as possible be reported to the Superintendent of the Coast Survey and promptly published.

The information derived from the trials of the experimental machinery was utilized in some degree in designing the machinery for the U. S. Revenue Steamer "Rush," and it having been found expedient to put machinery of different kinds in the two sister vessels, the "Dexter" and "Dallas," there resulted therefrom the series of trials of said vessels by a Joint Board of Naval and Revenue Marine Officers under the general direction of Chief Engineer Loring, U. S. N., and myself. C. E. E.

New York, November, 1874.

DESCRIPTION OF THE MACHINERY.

The engine and hull of the "Bache" were built in the year 1870, by Messrs. Pusey, Jones & Co., of Wilmington, Delaware. The engine was designed by Mr. Emery, the Consulting Engineer, and is of the steepled compound type, the larger cylinder, which is steam jacketed, being supported vertically upon frames as in ordinary vertical engines. The smaller cylinder, which is not steam jacketed, is supported above the other by four side columns. The pistons are attached to the same piston rod. Suitable pipes and valves are provided, so that the live steam can be supplied to the larger cylinder and excluded from the smaller, the former then working as a single engine. Ordinarily, when operating as a compound engine, the steam from upper cylinder passes to the chest of the lower through a large pipe, no pains having been taken to reduce the intermediate space, as the distribution of power between the two cylinders can easily be regulated by the adjustable cut-off on the larger.

Steam is distributed to each cylinder by a short slide valve at each end, and for both cylinders there are independently adjustable cut-off plates on the back of the main valves. The valve faces of the upper cylinder are carried out so that the valves of both cylinders are operated by continuous stems, but the ports, which lead directly out from the clearances, are shorter than usual for the upper cylinder and of the least possible length in the lower cylinder. The engine is provided with a surface condenser. The air pump is operated through the usual levers from the main crosshead. The circulating

pump is of the centrifugal pattern, operated by a small independent engine, directly connected.

The boiler is of the Scotch return tubular type, and of sufficient strength for a steam pressure of one hundred pounds, according to U. S. laws, though ordinarily worked at eighty pounds pressure. It is provided with a steam chimney arranged above the front connection in the usual manner and connected to the boiler by a large tube.

The following are the principal dimensions of the machinery:

ENGINE.

	High Pressure.	Low Pressure
Diameter of Cylinders, inches,	15·98	25·
Diameter of Piston Rods, "	2·5	3·625
Stroke of Pistons, "	24·00	24·00
Size of Cylinder Ports, "	9×1½	18×1½
Ratio of Piston Displacement to Capacity of Clearance and Passages,	·0486	·0405
Comparative effective Capacities of the two Cylinders,	1·00	2·4398
	·40987	1·00
Ratio capacities of Cylinders to capacities of Intermediate Chambers and Passages	2·6272	1·0768

BOILER.

Diameter,	8 ft. 2 inches.
Length,	12 ft.
Inside diameter of Furnace Flues,	34 inches.
Tubes, 90 in number, 9 ft. 9 inches long and 3 inches in diameter.	
Grate Surface,	31·16 sq. ft.
Calorimeter or area through tubes for draft,	3·78 "
Water Heating Surface,	950·10 "
Steam Heating Surface,	54·32 "
Ratio Grate Surface to Calorimeter,	8·25 "
Ratio Heating to Grate Surface,	30·50 "
Ratio Heating Surface to Calorimeter,	252·02 "
Ratio Calorimeter to Steam Space, (9 inches water above tubes,)	48·80 "

MANNER OF CONDUCTING THE EXPERIMENTS.

The trials were made with the vessel secured to the dock. A double tank of iron for measuring the water delivered from the surface

condenser was placed on the main deck in the gangway abreast of the engine, and a pipe with regulating cock in the same led from each compartment to a tank in the hold, from which the water was withdrawn by the engine feed pumps.

The water was delivered to the measuring tank directly by the air pump through a pipe with flexible termination, which could be directed into either compartment of tank. Each compartment held by calculation very nearly ten cubic feet, at the height of a central overflow partition, but the exact capacity was ascertained by weighing water into same of the average temperature of the feed.*

The measurement was made by filling one compartment until it overflowed into the other, which had been previously emptied; the supply was then changed to the latter, and when the surplus water in first had run off, that compartment was emptied, and cock on bottom of same closed in time to receive the overflow from the other, the operation being repeated alternately with each compartment.

To prevent the misplacing of the cocks the attendant gave notice when each compartment was nearly full, and when the water first broke over the partition a signal was given and the reading of engine counter was noted. A comparison of the differences of successive readings and constant attendance of two persons effectually prevented errors. On the next even minute after filling a tank the reading of engine counter was again taken, also the usual engine room data and the duration of experiments was fixed, so far as measurements were concerned, by the tank intervals and in respect to speed by the nearest time intervals.

By this plan the officer on watch had but one thing to do at a time; the principal calculations were left for office work; the experiment could be held to start and stop at such records as best showed the uniformity of condition desired for an experiment, and an interrupted run be accurately calculated up to the end of the tank interval immediately preceding the interruption.

Indicator Diagrams were taken every twenty minutes.

The water level in boiler was noted every time a tank was filled, but did not vary appreciably, as the condenser was quite tight and all leaks were of a trifling nature. The condensed water from jackets and intermediate chamber was collected and weighed in separate vessels,

*[An illustrated description of this tank will appear in the March number.—Ed.]

TABLE NO. 1, SHOWING THE RESULTS OF EXPERIMENTS WITH THE STEAM MACHINERY OF THE U. S. COAST SU

		MANNER IN WHICH ENGINE WAS OPERATED.	COMPOUND, WITHOUT USING STEAM JACKET, BUT DRAINING INTERMEDIATE CHAMBER.			
1	Designation of Runs	Number for reference	1	2	3	4
2		Designation in log	8	7	6	5
3	Time	Date of experiment, 1874	May 14.	May 14.	May 14.	May 12,
4		Duration of experiment, hours	1.833	2.066	2.133	1.733
5	Steam Cut-off and Expansion	Average steam pressure in boiler, lbs.	H. P. Cyl. | L. P. Cyl. 82.00	H. P. Cyl. | L. P. Cyl. 80.28	H. P. Cyl. | L. P. Cyl. 80.3125	H. P. Cyl. | L. P. 81.375
6		" cut-off in fractions of stroke, "	.231 | .503	.335 | .833	.405 | .779	.103 |
7		Ratio of expansion, "	3.75 | 9.146	2.73 | 6.658	2.31 | 5.634	6.91 | 16.
8	Vacuum and Barometer	Average vacuum in condenser, inches	24.00	24.321	24.656	24.50
9		" barometer, "	30.00	30.00	30.00	30.34
10		" " , lbs.	14.72	14.72	14.72	14.89
11	Temperatures (Fahrenheit Scale)	Air. Average temperature engine room, degrees	96.50	96.00	96.00	
12		" " fire room, "	84.00	86.33	86.33	81.375
13		Water. " " sea water, "	62.00	62.00	62.00	60.00
14		" " discharge water, "	87.00	92.00	91.33	82.00
15		" " hot well, "	98.00	100.00	105.33	110.00
16	Revolutions	Total revolutions	4685.	5912.	6305.	4042
17		Average " per hour	2555.91	2861.56	2955.93	2332.37
18		" " per minute	42.5985	47.6927	49.2655	38.873
19	Indicator Diagrams	Average initial pressure in cylinder above atmosphere, lbs.	75.00 | 1.00	76.33 | 2.458	73.00 | 3.9	75.75 | 1.
20		" total initial pressure in cylinder, "	89.72 | 15.72	91.05 | 17.178	87.72 | 18.62	90.64 | 15.
21		" " terminal " " , "	24.345 | 7.72	30.47 | 9.18	32.32 | 10.02	20 76 | 10.
22		" " cushion " " , "	28.595 | 5.532	29.52 | 5.97	32.42 | 6.02	26.39 | 6.
23		" back pressure above atmosphere at beginning of stroke, small cylinder, "	2.800	4.333	5.280	1.700
24		" total back pressure at half stroke, large cylinder, "	| 3.300	| 3.414	| 3.328	| 3.
25		" mean effective pressure, "	34.801 | 8.153	43.514 | 9.7588	45.137 | 11.2756	34.484 | 10.
26		Estimated friction pressure, "	.75 | 2.25	.75 | 2.25	.75 | 2.25	.75 | 2.
27	Power	Indicated horse-power (effective)	35.586 | Both. 55.928	49.85 | Both. 77.06	5332. | Both. 85.81	22.852 | Bot 46.
28		Net horse-power	34.82 | Both. 49.548	48.874 | Both. 69.812	52.434 | Both. 78.447	22.102 | Bot 40.
29	Water	Total weight of water received from hot well, lbs.	2391.00	3586.50	4184.25	1793.25
30		" " " " small chest and steam jacket, "				132.25
31		" " " " intermediate chamber, "	36.00	79.00	62.00	95.75
32		" " " ascertained by measurement, "	2427.00	3665.50	4246.25	2021.25
33		Revolutions using same	4678.	5909.	6301.	4047.
34		Time using same, hours	1.826	2.0649	2.132	1.735
35		Hourly quantities. Water per hour as ascertained by measurement, lbs.	1329.13	1775.14	1991.67	1164.9
36		" " " " " indicator diagrams, "	662.046 | 710.228	1207.6 | 948.82	1318.97 | 1059.45	673.673 | 887.
37		Proportional quantities. Per centage of total water received from jacket and small chest,				.065
38		" " " " " " intermediate chamber	.015	.0215	.014	.047.
39		" " " " " " jacket, chest & "	.015	.0215	.014	.112
40		" " " " accounted for by indicator	.64857 | .53435	.68098 | .5345	.66224 | .53194	.57964 |
41	Coal and Refuse	Total coal consumed, lbs.				
42		Average coal consumed per hour, "				
43		Coal consumed per square foot of grate per hour, "				
44		Percentage refuse from coal				
45		Combustible per hour, lbs.				
46	Performance of Engine	Water per indicated horse-power per hour by measurement, lbs.	23.765	23.036	23.21	25.1082
47		" " " " " " indicator, "	15.413 | 12.699	15.671 | 12.312	5.871 | 12.346	14.553 | 18.
48		" " net " " " measurement, "	26.8251	25.4274	25.3887	28.698
49	Performance of Engine and Boiler	Coal per indicated horse-power per hour, lbs.	Calculated. 2.602	Calculated. 2.522	Calculated. 2.541	Calculated. 2.749
50		" " net " " " "				
51		Combustible per indicated horse-power per hour, "				
52		" " " net " " " "				
53	Performance of Boiler	No. lbs. water evap'd per lb. coal at observed pressure and temp., lbs.				
54		Equivalent evaporation from atmospheric pressure and temp. 100°, "				
55		" " " " " " 212°, "				
56		No. lbs. water evap'd per lb. combustible at obs'v'd press. and temp., "				
57		Equivalent evaporation from atmospheric pressure and temp. 100°, "				
58		" " " " " " 212°, "				

To accompany Report of CHARLES E. EMERY, Consulting Engineer.

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WITHOUT USING STEAM JACKET, BUT NING INTERMEDIATE CHAMBER.			COMPOUND, USING STEAM JACKET,			
	2	3	4	5	6	
	7	6	5	4	3	
	May 14. 2.066	May 14. 2.133	May 12, 1.783	May 12. 2.066	May 12. 1.933	
yl.	H. P. Cyl. | L. P. Cyl. 80.28	H. P. Cyl. | L. P. Cyl. 80.3125	H. P. Cyl. | L. P. Cyl. 81.375	H. P. Cyl. | L. P. Cyl. 80.333	H. P. Cyl. | L. P. Cyl. 80. 214	H.
08	.335 | .833	.405 | .779	.108 | .820	.329 | 8.31	.318 | .831	
46	2.73 | 6.658	2.31 | 5.634	6.91 | 16.85	3.77 | 9.19	2.86 | 6.975	
	24.321 30.00 14.72	24.656 30.00 14.72	24.50 30.34 14.89	26.50 30.34 14.89	26.50 30.34 14.89	
	96.00 86.33	96.00 86.33	81.375	80.00	80.00 78.00	
	62.00 92.00 100.00	62.00 91.33 105.33	60.00 82.00 110.00	60.00 79.00 104.00	60.00 78.50 103.00	
	5912. 2861.56 47.6927	6305. 2955.93 49.2655	4042 2332.37 38.873	5973. 2891.00 48.185	6168. 3190.89 53.1815	
0	76.33 | 2.458	73.00 | 3.9	75.75 | 1.00	77.125 | 4.00	78.58 | 6.25	
2	91.05 | 17.178	87.72 | 18.62	90.64 | 15.89	92.015 | 18.89	93.47 | 21.14	
2	30.47 | 9.18	32.32 | 10.02	20.76 | 10.39	27.39 | 11.89	33.72 | 12.93	
32	29.52 | 5.97	32.42 | 6.02	26.39 | 6.77	30.03 | 4.89	36.29 | 4.89	
	4.333	5.280	1.700	5.000	7.700	
0	3.414	3.328	3.600	3.050	3.264	
3	43.514 | 9.7588	45.137 | 11.2756	24.484 | 10.341	35.39 | 13.014	42.34 | 14.484	
5	.75 | 2.25	.75 | 2.25	.75 | 2.25	.75 | 2.25	.75 | 2.25	
	Both.	Both.	Both.	Both.	Both.	
28	49.85 | 77.06	5332. | 85.81	22.852 | 46.4	40.87 | 77.453	54.06 | 99.181	
	Both.	Both.	Both.	Both.	Both.	
8	48.874 | 69.812	52.434 | 78.447	22.162 | 40.59	40.005 | 70.335	53.104 | 91.216	
	3586.50	4184.25	1793.25	2988.75	3586.50	
	79.00	62.00	132.25	235.25	199.00	
	3665.50	4246.25	95.75	91.00	98.00	
	5909.	6301.	2021.25	3315.00	3883.50	
	2.0649	2.132	4047.	5974.	6145.	
			1.735	2.00681	1.9258	
	1775.14	1991.67	1164.9	1604.31	2016.56	
28	1207.6 | 948.82	1318.97 | 1059.45	673.673 | 857.824	1092.47 | 1220.36	1485.23 | 1464.9	17
			.065	.070	.051	
	.0215	.014	.047.	.030	.025	
	.0215	.014	.112	.100	.076	
435	.68028 | .5345	.66294 | .58194	.57964 | .73800	.68095 | .76007	.73651 | .79643	
	23.036	23.21	25.1082	20.7133	20.332	
9	15.671 | 12.312 25.4274	5.871 | 12.346 25.3887	14.553 | 18.532 28.698	14.104 | 15.756 22.8095	14.974 | 14.709 22.1074	
	Calculated. 2.522	Calculated. 2.541	Calculated. 2.749	Calculated. 2.268	Calculated. 2.227	

E. EMERY, CONSULTING ENGINEER
n of Superintendent of the U. S. Coast Survey.

AT BALTIMORE, MD., IN MAY 1874. (FOR DIMENSIONS OF ENGINE AND BOILER, SEE SEPARATE TABLE.)

M JACKET, AND DRAINING INTERMEDIATE CHAMBER.

	7	8	9	10	11	12	13	14	15	16	17
	2	1st Evap.	2d Evap.	1	14	13	12	11	10	9	15
	May 12.	May 14.	May 15,	May 12.	May 18.	May 18.	May 18.	May 18.	May 18.	May 18.	May 18.
	1.983	7.066	15.233	2.00	1.80	1.983	2.05	2.10	1.683	2.116	1.883
L. P. Cyl.	H. P. Cyl. | L. P. Cyl.	H. P. Cyl. | L. P. Cyl.	H. P. Cyl. | L. P. Cyl.	H. P. Cyl. | L. P. Cyl.	Large Cyl.	Large Cyl.	Large Cyl.	Large Cyl.	Large Cyl.	Large Cyl.	Large Cyl.
214	80.125	79.96	79.7	79.1	81.00	79.625	78.11	80.833	81.071	79.5	80.875
.831	.396 | .802	.398 | .822	.4519 | .735	.554 | .795	.0475	.096	.155	.042	.081	.163	.437
6.975	2.35 | 5.732	2.34 | 5.707	2.00 | 5.097	1.74 | 4.24	11.82	7.02	5.32	12.62	8.57	5.11	2.18
50	26.562	26.115	24.39	26.5	24.00	23.78	24.22	24.66	25.285	25.52	24.00
34	30.34	30.00	29.15	30.34	29.83	29.83	29.83	29.83	29.83	29.83	29.83
89	14.89	14.72	14.31	14.89	14.64	14.64	14.64	14.64	14.64	14.64	4.64
00	76.66	83.70	90.00	78.00	86.3	86.75	86.00	85.00	84.66	75.25	85.00
00	75.33	83.80	85.06	76.66	84.66	84.00	83.33	81.00	80.33	74.75	83.00
00	60.00	61.90	64.66	60.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
50	79.66	90.20	92.53	80.66	96.66	94.25	93.00	91.00	95.00	93.75	100.50
00	102.00	106.60	125.26	115.33	133.66	131.50	129.33	121.33	120.66	117.00	137.50
	6705.	23568.	49008.	7268.	4025.	5345.	5790.	5030.	4671.	6836.	5116.
89	3381.	3335.4	3217.22	3634.	2236.11	2995.41	2924.39	2395.24	2774.9	3230.02	2716.94
1815	56.34	55.59	53.62	60.56	37.2685	44.923	47.073	39.9206	46.248	53.84	45.282
6.25	75.41 | 8.66	75.32 | 8.96	74.47 | 7.52	72.41 | 13.02	74.3	76.1	72.75	74.16	75.5	76.1	26.9
21.14	90.30 | 23.55	90.04 | 23.68	88.78 | 22.83	87.20 | 28.51	88.94	90.74	87.39	88.80	90.14	90.74	41.54
12.98	38.30 | 14.23	36.95 | 14.31	34.40 | 12.98	47.05 | 16.89	10.74	12.34	15.80	10.56	11.73	16.64	16.84
4.89	35.05 | 4.29	40.94 | 5.02	37.69 | 6.26	42.89 | 4.89	8.84	8.64	9.89	7.84	7.64	9.03	8.73
	9.266	10.066	9.200	14.733							
3.264	3.328	3.360	3.253	3.317	4.560	4.400	4.400	2.980	2.774	3.680	4.720
14.484	42.938 | 15.88	45.3748 | 13.961	43.0008 | 14.908	45.83 | 19.34	21.543	27.278	32.328	23.449	27.54	36.94	25.159
2.25	.75 | 2.25	.75 | 2.25	.75 | 2.25	.75 | 2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Both.	Both.	Both.	Both.	Both.							
99.181	58.086 | 110.514	60.502 | 106.028	55.4372 | 102.263	65.911 | 134.53	47.24	71.75	89.141	54.838	74.618	116.015	66.74
Both.	Both.	Both.	Both.	Both.							
91.216	57.068 | 102.069	59.5617 | 97.7014	54.4716 | 94.23	65.112 | 125.75	42.329	65.83	82.96	49.574	68.518	109.37	60.809
50	4184.25	15302.40	32278.50	5379.75	2988.75	4184.25	4782.0	2988.75	2988.75	5379.75	4184.25
00	209.	889.25	1977.00	232.00				126.25	55.00	127.00	64.35
00	70.50	249.00	599.25	77.00	7.00	2.00	12.0	14.0	8.30	33.00	4.68
50	4463.75	16440.65	34854.75	5688.75	2995.75	4186.25	4794.0	3129.0	3052.05	5539.75	4253.28
	6706.	23547.	49001.	7259.	4085.	5314.	5787.	5041.0	3831.	6870.	5090.
9258	1.954	7.059	15.230	1.9075	1.808	1.971	2.0489	2.1046	1.698	2.142	1.873
56	2284.42	2329.08	2288.558	2847.9	1656.94	2125.0	2339.7	1486.74	1797.4	2986.25	2270.83
1464.9	1778.07 | 1710.17	1681.00 | 1696.95	1518.76 | 1485.66	2323.1 | 2180.61	993.364	1179.22	1546.81	900.29	1162.25	1885.67	1604.76
051	.046	.054	.056	.040				.0405	.018	.022	.015
025	.015	.015	.016	.010	.002	.0005	.002	.004	.0027	.006	.001
076	.061	.039	.072	.050	.002	.0005	.002	.0445	.0207	.028	.016
.73643	.77835 | .74888	.72176 | .72850	.66363 | .64916	.81572 | .76569	.59951	.55492	.66111	.60554	.64663	.70197	.70668
			3818.								
			250.64								
			8.84								
			19.8								
			201.01								
382	20.3648	21.9661	22.3798	21.169	35.075	29.616	26.247	27.113	24.088	23.154	34.026
14.769	15.851 | 15.251	15.854 | 16.004	14.852 | 14.528	17.268 | 16.209	21.028	17.755	17.352	16.418	15.576	16.253	24.045
1074	21.9089	23.8385	24.287	22.647	39.144	32.280	28.21	29.99	26.23	24.56	37.3683
ated.	Calculated.	Calculated.	Actual.	Calculated.	Calculated.	Calculated.	Calculated.	Calculated.	Calculated.	Calculated.	Calculated.
227	2.220	2.405	2.451	2.318	3.841	3.243	2.874	2.969	2.638	2.535	3.726
			2.660								
			1.966								
			2.133								
			9.131								
			9.206								
			10.281								
			11.385								
			11.479								
			12.820								

and emptied into the tank from which the boiler was at the time being fed.

One experiment was made of sufficient length to determine accurately the evaporation of the boiler; and it having been shown that the water measurement was substantially the same from hour to hour when the conditions remained uniform, the opportunity was embraced to try a number of experiments of short duration showing the results under varied conditions, using the water measurement only. Previous to the evaporation trial, a quantity of coal was, in the presence of an officer, measured into a distinct portion of the coal bunkers, and the remainder of the bunkers boarded up. From this measured quantity the coal was taken as required for the fires, and each bucket made to balance accurately a fixed weight on a scale. The weighing was done by a careful machinist who had no knowledge of the quantity originally measured.

In the first experiment tried in this way the two methods of determining the quantity did not agree, and the coal measurement was rejected. Upon repeating the experiment there was a very close agreement, so the weighed quantity was adopted as correct.

The coal used was anthracite of fair quality.

The results of these experiments are shown in the following table, which is in such form that little explanation will be necessary. See supplementary sheet.

It will be observed that the experiments are arranged by the degree of expansion, under four general titles, two referring to the engine when compounded, and two to experiments with large cylinder when used separately; trials being made in each case at different degrees of expansion with and without using the steam jackets on the large cylinder. All the experiments were made with an approximate steam pressure of 80 pounds, except the last.

The actual performances will be found in lines 46 to 58 inclusive. The previous lines showing the several observed and calculated quantities upon which the performances are based. The weights of water withdrawn from the jackets and intermediate chamber are separately set forth, also the percentage which these quantities form of the total water used. The water collected from jackets and intermediate chamber having been evaporated in the boiler is in all cases included in making up line 35, showing the total weight of water used per hour, upon which the cost of the power is based.

The quantities which will probably be found most convenient for comparison are those shown in line 46, viz.: the Actual Weight of Water used per Indicated Horse Power per Hour.

To Capt. C. P. Patterson,
Supt. U. S. Coast Survey,
New York, August, 1874.

CHAS. E. EMERY,
Consulting Engineer U. S. Coast Survey.

REMARKS ON THE EXPERIMENTS MADE WITH A SMALL NON-CONDENSING STEAM-ENGINE BY B. DONKIN & CO., LONDON, SHOWING THE RELATIVE ECONOMIC EFFICIENCY OF STEAM-JACKETING, AND OF USING STEAM WITH DIFFERENT MEASURES OF EXPANSION.

By Chief Engineer B. F. Isherwood, U. S. Navy.

[Continued from Vol. lxix, page 28.]

THE ECONOMY OF THE STEAM JACKET.

As in the case of using steam with different measures of expansion, so in that of using the steam-jacket, the economy, though always in favor of the steam-jacket, will be found to vary in quantity with the ratio of the mean total pressure to the back pressure, and with the absolute mean total pressure; but the economy is not affected by the measure of expansion used, provided the mean total pressure and the back pressure are constant. The greater the ratio of the mean total pressure to the back pressure, *ceteris paribus*, the greater the economy of the steam-jacket; and the less the absolute mean total pressure, *ceteris paribus*, the greater the economy of the steam-jacket. For example: In the case of using the steam with the measure of expansion due to cutting it off at $\frac{3}{8}$ of the stroke of the piston, columns A and B, we find, making the comparison for the cost of the total horse-power in pounds of feed-water consumed per hour that, when steam was in the jacket this cost was 34·083 pounds, and when steam was not in the jacket, 40·076 pounds, showing an economy of $\left(\frac{40{\cdot}076 - 34{\cdot}083 \times 100}{40{\cdot}076}\right) = 14{\cdot}95$ per centum in favor of the jacket,

assuming, for unity, the cost without the jacket. If, now, a similar comparison be made for the experiment in columns E and F, in which the same back pressure and nearly the same mean total pressure existed as in experiments A and B, but in which the measure of expansion used was that due to cutting off at $\frac{3}{8}$ of the stroke of the piston, we find the cost of the total horse-power, with steam in the jacket, to be 39·428 pounds of feed-water consumed per hour, and without steam in the jacket 46·016 pounds, showing an economy in favor of the jacket of $\left(\frac{46{\cdot}016 - 39{\cdot}428 \times 100}{46{\cdot}016}\right) = 14{\cdot}32$ per centum, or almost exactly the same as when with the same pressures the steam was cut off at $\frac{3}{8}$ of the stroke of the piston in experiments A and B. Hence, it appears that, *ceteris paribus*, the economy of the steam-jacket is not affected by the measure of expansion with which the steam is used.

In the case of experiments C and D, in which the steam was cut off at $\frac{3}{8}$ of the stroke of the piston as in experiments E and F, and in which the back pressure was the same, but in which the mean total pressure was greatly higher, making also the ratio of the mean total pressure to the back pressure much higher, the effect of this higher mean total pressure and its higher ratio to the back pressure becomes very apparent in the reduction of the economy of the steam jacket. Making the comparison for the cost of the total horse-power in pounds of feed-water consumed per hour, we find it when steam is in the jacket, to be 39·008 pounds, and when steam is not in the jacket, 43·039 pounds, showing an economy for the jacket of only $\left(\frac{43{\cdot}039 - 39{\cdot}008 \times 100}{43{\cdot}039}\right)$ $= 9{\cdot}04$ per centum, instead of 14·32 per centum, as in the case of experiments E and F, made with the same measure of expansion, but with different mean total pressure.

The amount of economy given by the steam-jacket, as determined for the total horse-power, is no indication of its amount for the net horse-power, that amount being sometimes greater and sometimes smaller for the net horse-power than for the total horse-power, according to the conditions of the case. For example: in experiments A and B the cost of the net horse-power in pounds of feed-water consumed per hour when steam was in the jacket was 60·632 pounds, and ween steam was not in the jacket, 78·128 pounds, showing an economy

of $\left(\frac{78{\cdot}128 - 60{\cdot}722 \times 100}{78{\cdot}128}\right) = 22{\cdot}27$ per centum for the jacket, instead of 14·95 per centum, as given when computed for the total horse-power.

Again, in the case of experiments C and D, the cost of the net horse-power, when steam was in the jacket, was 55·890 pounds of feed-water consumed per hour, and when steam was not in the jacket, 65·998 pounds, showing an economy of $\left(\frac{65{\cdot}998 - 55{\cdot}890 \times 100}{65{\cdot}998}\right) =$ 15·32 per centum for the jacket, instead of 9·04 per centum as given when computed for the total horse-power.

Finally, in the case of experiments E and F, the cost of the net horse-power when steam was in the jacket, was 81·527 pounds of feed-water consumed per hour, and when steam was not in the jacket, 91·133 pounds, showing an economy of $\left(\frac{91{\cdot}133 - 81{\cdot}527 \times 100}{91{\cdot}133}\right) =$ 10·54 per centum for the jacket, instead of 14·32 per centum, as given when computed for the total horse-power.

Of course, the commercial value of the steam-jacket, like the commercial values of the different measures of expansion, is that which is given for the net horse-power, and its amount depends entirely upon the conditions of the case, each problem requiring a particular solution.

THE QUANTITY OF STEAM CONDENSED IN THE JACKET TO FURNISH THE HEAT IMPARTED TO THE CYLINDER.

The purpose of the steam-jacket is to furnish heat to the cylinder, and thereby prevent the condensation of steam within the same. This heat can only be obtained by the condensation of steam in the jacket, and the experiments enable us to determine for the experimental conditions, the weight of steam thus condensed in the two cases of using the steam with measures of expansion due to cutting it of at $\frac{3}{8}$ and at $\frac{3}{8}$ of the stroke of the piston.

The experimental data, line 5, give 30 pounds for the weight of steam condensed per hour by external radiation from the steam-pipe and steam-jacket, when the engine was not in operation, but the jacket remained filled with steam of the boiler pressure, and this quantity was constant. The data also gives the weight of steam condensed per hour in the steam-jacket when filled with steam of the same boiler-

pressure, but with the engine in operation, line 6, consequently the subtraction of the former from the latter quantity gives the weight of steam condensed in the jacket to furnish the heat imparted to the cylinder and acting for the prevention of condensation, within the same.

During experiment A, when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, the quantity of heat imparted to the cylinder by the steam-jacket, was the quantity measured by the condensation per hour of (53·333—30·000 =) 23·333 pounds of steam of the boiler pressure; or, as the latent heat of the boiler-pressure (45 pounds per square inch above the atmosphere) is 908·418 units, there were imparted per hour to the cylinder by the jackets (23·333 × 908·418 =) 21196·420 units of heat.

During experiment C, when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, the quantity of heat imparted to the cylinder by the steam-jacket, was the quantity measured by the condensation per hour of (47·636 — 30·000 =) 17·636 pounds of steam of the boiler-pressure, or there were imparted per hour to the cylinder by the jacket (17·636 × 908·418 =) 16020.860 units of heat.

During experiment E, when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, the quantity of heat imparted to the cylinder by the steam-jacket, was the quantity measured by the condensation per hour of (47·000 — 30·000 =) 17·000 pounds of steam of the boiler-pressure, or there were imparted per hour to the cylinder by the jacket (17·000 × 908·418 =) 15443·106 units of heat.

The great efficiency of the steam-jacket in economizing the steam, will appear from the following considerations; taking, first, the data of experiment A, in which the steam is cut off at $\frac{3}{8}$ of the stroke of the piston. If, in that experiment we deduct from the weight of feed-water pumped into the boiler per hour, the weight of steam condensed per hour by external radiation, and divide the remainder by the total horse-powers developed by the engine, we shall obtain for the cost of the total horse-power $\left(\frac{361·244 - 30·000}{10·599} = \right)$ 31·252 pounds of feed-water consumed per hour. Taking, now, the data of experiment B, and performing the same calculation, we obtain for the cost of the total horse-power $\left(\frac{354·155 - 30·000}{8·837} = \right)$ 36·682 pounds of feed-water consumed per hour. The difference of 5·430 pounds in these two

cases is due entirely to the heat imparted by the jacket to the cylinder, and for the 10·599 total horse-powers developed by the engine during experiment A, would amount to ($10{\cdot}599 \times 5.430 =$) 57·55257 pounds per hour, and as the total heat of the steam of the boiler pressure is 1203·0762 units, while the temperature of the back pressure is 216·33 degrees Fahrenheit, the units of heat in this quantity of steam would be ($986{\cdot}7463 \times 57{\cdot}55257 =$) 56789·785, and the waste of this quantity of heat in the cylinder by the condensation therein of the steam due to other causes than the production of the power, is prevented by the condensation of a sufficient quantity of steam in the jacket to furnish 21196·420 units of heat, as previously shown.

Again, in the case of experiment C, in which the steam is cut off at $\frac{2}{3}$ of the stroke of the piston, if we deduct from the weight of feed-water pumped into the boiler per hour, the weight of steam condensed per hour by external radiation, and divide the remainder by the total horse-powers developed by the engine, we shall obtain for the cost of the total horse-power $\left(\frac{562{\cdot}145 - 30{\cdot}000}{14{\cdot}411} =\right)$ 36·926 pounds of feed-water consumed per hour. Taking, now, the data of experiment D, and performing the same calculation, we obtain for the cost of the total horse-power $\left(\frac{556{\cdot}364 - 30{\cdot}000}{12{\cdot}927} =\right)$ 40·718 pounds of feed-water consumed per hour. The difference of 3·792 pounds in these two cases is due entirely to the heat imparted by the jacket to the cylinder, and for the 14·411 total horse-powers developed by the engine during experiment C would amount to ($14{\cdot}411 \times 3{\cdot}792 =$) 54·646512 pounds of feed-water consumed per hour, and as the total heat of the steam of the boiler pressure is 1203·0762 units, while the temperature of the back pressure is 216·33 degrees Fahr., the units of heat in this quantity of steam would be ($986{\cdot}7463 \times 54{\cdot}646512 =$) 53922·243; and the waste of this quantity of heat in the cylinder by the condensation therein of the steam due to other causes than the production of the power, is prevented by the condensation of a sufficient quantity of steam in the jacket to furnish 16020·860 units of heat, as previously shown.

Finally, in the case of experiment E, in which the steam is cut off at $\frac{2}{3}$ of the stroke of the piston, if we deduct from the weight of feed-water pumped into the boiler per hour, the weight of steam condensed per hour by external radiation, and divide the remainder by the total

horse-powers developed by the engine, we shall obtain for the cost of the total horse-power $\left(\frac{334{\cdot}667 - 30{\cdot}000}{8{\cdot}488} =\right)$ 35·894 pounds of feed-water consumed per hour. Taking now the data of experiment F, and performing the same calculation, we obtain for the cost of the total horse-power $\left(\frac{419{\cdot}667 - 30{\cdot}000}{9{\cdot}120} =\right)$ 42·727 pounds of feed-water consumed per hour. The difference of 6·833 pounds in these two cases is due entirely to the heat imparted by the jacket to the cylinder, and for the 8·488 total horse-powers developed by the engine during experiment **E**, would amount to $(8{\cdot}488 \times 6{\cdot}833 =)$ 57·998504 pounds of feed-water consumed per hour, and as the total heat of the steam of the boiler-pressure is 1203·0762 units, while the temperature of the back pressure is 216·33 degrees Fahr., the units of heat in this quantity of steam would be $(986{\cdot}7463 \times 57{\cdot}998504 =)$ 57229 809; and the waste of this quantity of heat in the cylinder by the condensation therein of the steam due to other causes than the production of the power, is prevented by the condensation of a sufficient quantity of steam in the jacket to furnish 15443·106 units of heat, as previously shown. The steam-jacket in the case of experiment E, is more efficient than in experiment C, giving a greater economy, though in both cases the steam was cut off at $\frac{3}{8}$ of the stroke of the piston. The reason of this is that the less absolute mean total pressure in experiment F, produced by throttling, gave a much greater cylinder condensation to be acted on preventively by the steam-jacket.

The use of the steam-jacket when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, effected for every unit of heat imparted by the jacket to the cylinder, a saving within the latter of 2·619 units by the prevention of condensation.

The use of the steam-jacket when the steam was cut off at $\frac{5}{8}$ of the stroke of the piston, and the mean total pressure was about the same as when the steam was cut off at $\frac{3}{8}$ of the stroke of the piston, effected for every unit of heat imparted by the jacket to the cylinder, a saving within the latter of 3·706 units by the prevention of condensation.

The use of the steam-jacket when the steam was cut off at $\frac{5}{8}$ of the stroke of the piston, and the mean total pressure was about fifty per centum greater than in the preceding two cases, effected for every unit of heat imparted by the jacket to the cylinder, a saving within the latter of 3·366 units by the prevention of condensation.

In the preceding discussion, the loss of heat by external radiation, when steam was not in the jacket, has been assumed to be the same as when steam was in the jacket, which is not quite true, as in the former case this loss must have been much less, owing to the considerably less surface exposed; the assumption, therefore, is against the steam-jacket, making its economic efficiency appear somewhat less than it really is. I have done the best I could, however, with the data at my command, but the reader must remember that the engine was not properly designed for making critically accurate experiments. The results, nevertheless, are reasonably correct, and are far too valuable to be rejected because all the conditions were not just what they could have been wished.

THE QUANTITY OF STEAM CONDENSED IN THE CYLINDER BY CAUSES OTHER THAN DUE TO EXTERNAL RADIATION AND TO THE PRODUCTION OF THE POWER.

It is very evident there must always be a condensation of steam in a steam-engine, due to external radiation of heat. So long as the surrounding atmosphere is at a less temperature than that of the steam within the cylinder, so long will there be a condensation of steam, let the cylinder be enveloped with what non-conducting substance it may. This is an inevitable waste of steam in an engine easily understood, and the only question is to reduce it as much as possible by the employment of the best non-conducting envelope. In the experimental engine, the loss of steam from this cause alone averaged 7 per centum of the steam evaporated in the boiler. That is to say, the condensation in the steam-pipe and engine, exclusive of the condensation in the boiler, averaged this quantity.

It is equally evident that there is another cause of condensation in steam-engines just as inevitable as the preceding, and this condensation, resulting from the necessary transformation of heat into the total power developed, takes place when the steam is used without expansion, not only in the cylinder, but in the steam-pipe and boiler, in fact, everywhere between the water-level in the latter and the piston in the former. When, however, the steam is used with expansion, the condensation after the communication with the boiler is closed, takes place in the cylinder only. The shorter the cut-off, therefore, the more of this condensation takes place in the cylinder.

In experiment A, with steam in the jacket and the cut off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the produc-

tion of the power was 8·28 per centum of the quantity of steam evaporated in the boiler; but it was 9·72 per centum of the quantity of steam which actually entered the cylinder. Yet even after taking account of this condensation and of those due to external radiation and to the impartation of heat by the steam-jacket to the cylinder, and also of the quantity of steam exhausted at the end of the stroke of the piston, line 22, there still remains an unaccounted for balance, line 26, of 11·40 per centum of the quantity of steam evaporated in the boiler. How could this large per centum have escaped measurement? By simple re-evaporation from the cylinder's inner surfaces and passage out into the atmosphere as vapor during the exhaust stroke of the cylinder. The steam-jacket, efficient as it was, was not able to prevent this large condensation in the cylinder; and doubtless more too, but the re-evaporation of which, under the lessening pressure during the steam stroke after the cut-off valve closed, by means of its contained heat and that absorbed from the cylinder's inner surfaces, took place before the end of the stroke of the piston, and was therefore measured in the quantity on line 22.

Again, in experiment C, with the steam in the jacket, and the cut-off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the production of the power was 7·24 per centum of the quantity of steam evaporated in the boiler; but it was 7·91 per centum of the quantity of steam which actually entered the cylinder. In this case, as in the previous one, there still remains a considerable quantity of steam unaccounted for, after including the condensations due to the external radiation and to the production of the power, with the quantity of steam exhausted at the end of the stroke of the piston (line 22); but this unaccounted for quantity is much less with the longer cut-off, being only, with the $\frac{3}{8}$ cut-off, 4·45 per centum of the quantity of the steam evaporated in the boiler, instead of the 11·40 per centum with the $\frac{3}{8}$ cut-off, showing that the shorter the cut-off, the greater is the cylinder condensation due to other causes than external radiation and the production of the power. As, in the preceding case, too, this unaccounted for portion of condensed steam was re-evaporated from the inner cylinder surfaces into the atmosphere during the exhaust stroke of the piston.

Finally, in experiment E, with steam in the jacket, and the cut-off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the production of the power was 7·16 per centum of the quantity of steam

evaporated in the boiler; but it was 8·33 per centum of the quantity of steam which actually entered the cylinder. In this case, the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than due to the external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 4·90 per centum of the quantity evaporated in the boiler.

The preceding three determinations for experiments A, C, and E, are for the condition of steam in the jacket. When, however, there is no steam in the jacket, as in experiments B, D, and F, the condensation of steam in the cylinder by causes other than those due to external radiation and to the production of the power, is very much greater. In these experiments, too, as in the preceding ones, this enormous quantity of steam after being condensed in the cylinder is re-evaporated into the atmosphere during the exhaust stroke of the piston.

For instance: in experiment B, with no steam in the jacket, and the cut-off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the production of the power was 7·05 per centum of the quantity of steam evaporated in the boiler; but it was 7·70 per centum of the quantity of steam which actually entered the cylinder less the quantity condensed by external radiation. In this case, the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than those due to external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 26·41 per centum of the quantity evaporated in the boiler, or about $2\frac{1}{2}$ times as much as in the case (experiment A) when steam was in the jacket, other things being equal.

Again, in experiment D, with no steam in the jacket, and the cut-off at $\frac{3}{8}$ of the stroke of the piston, the condensation of steam due to the production of the power was 6·56 per centum of the quantity of steam evaporated in the boiler; but it was 6·93 per centum of the quantity of steam which actually entered the cylinder less the quantity condensed by external radiation. In this case the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than those due to external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 16·77 per centum of the quantity evaporated in the boiler, or about 4 times as much as in the case (experiment C) when steam was in the jacket, other things being equal.

Finally, in experiment F, with no steam in the jacket, and the cut-off at $\frac{3}{4}$ of the stroke of the piston, the condensation of steam due to the production of the power was 6·14 per centum of the quantity of steam evaporated in the boiler; but it was 6·61 per centum of the quantity of steam which actually entered the cylinder less the quantity condensed by external radiation. In this case the quantity of steam unaccounted for, which was condensed in the cylinder by causes other than those due to external radiation and to the production of the power, and re-evaporated into the atmosphere during the exhaust stroke of the piston, was 19·76 per centum of the quantity evaporated in the boiler, or about 4 times as much as in the case (experiment E) when steam was in the jacket, other things being equal.

The experiments above discussed have a particular interest at the present time, owing to the extensive introduction of the compound engine with steam-jackets, high pressure steam, and excessively large measures of expansion; and to its superseding, in great degree, the ordinary steam-engine without steam-jackets and with steam of medium pressure used with small measures of expansion. The compound engine does indeed give an economic superiority ranging from one-fifth for medium sized engines, to one eighth for large ones; but this economy is due wholly and solely to the employment of the steam-jacket, and vanishes whenever the ordinary steam-engine is steam-jacketed also. The higher pressures and greater measures of expansion used with the compound engine are absolutely unproductive of any economic effect, their disadvantages just about balancing their advantages, but leaving all the very serious mechanical difficulties due to the higher pressures, heavier and bulkier boilers, and larger cylinders for the development of equal power, on the side of the compound engine. All that is required to give the ordinary steam-engine, when in good condition, the same economic result as the compound engine, is to simply steam-jacket its cylinder, without changing either the steam-pressure or measure of expansion used. The mistake has been made of attributing to the mere compounding of the cylinders, a result due entirely to the use of the steam-jacket, an appendage as easily applied to the one kind of engine as the other. It was quite overlooked in comparing the experimental economic results from the compound and the ordinary engine, that the former had been given the advantage of a steam-jacket which was omitted in the other. Whenever the steam-jacket was used in both cases, the results were equal.

EFFICIENCY OF FURNACES BURNING WET FUEL.

AS DETERMINED BY EXPERIMENTS ON A LARGE SCALE.

By Professor R. H. Thurston, A. M., C. E.

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(Continued from Volume lxix, page 59.)

CONCLUSION.

45. Comparing the quantities of heat actually utilized by transfer from the fuel to the boiler, we obtain as the measure of the actual comparative efficiencies of the two furnaces $4{\cdot}24 \div 3{\cdot}19 = 1{\cdot}33$, the Thompson excelling the Crockett 33 per cent. A number of circumstances combine to make the actual difference somewhat greater than the record here indicates, but this result may probably be taken to represent practically the relative economical standing of the two furnaces.

46. Experiments on dry pine wood, made by Prof. Johnson during his extended and invaluable examination of American coals,* for the U. S. Navy, furnish a standard of comparison which will be useful here. One cord of well-seasoned yellow pine wood weighed 2689·2 pounds—10 per cent. more than a cord of thoroughly air-dried spent tan bark—and one cubic foot weighed 21 pounds. Experiments on evaporative power showed, as a mean result, an effect equivalent to the evaporation of 4·69 pounds of water from 212°, under atmospheric pressure, per pound of wood consumed, the temperature of chimney flue being 315·2°, and the wood burning at the rate of 15.87 pounds per square foot of grate per hour, under a boiler having a ratio of heating to grate surface of 26·83 to 1.

47. Comparing this result, as a standard, with the evaporation obtained in the two wet fuel furnaces, per pound of fuel, exclusive of water, we get for the Thompson furnace $\frac{5{\cdot}68}{4{\cdot}69} = 1{\cdot}21$, and for the Crockett, $\frac{4\,41}{4{\cdot}69} = 0{\cdot}94$. The Thompson furnace is thus seen to have given a better result per pound of ligneous combustible when burning wet tan than was obtained in the ordinary steam-boiler furnace, burning seasoned yellow pine, this superiority reaching 21 per cent. The

* Report to the Navy Department on American Coals. By Walter R. Johnson Washington, 1844, pp. 546–550.

Crockett furnace had 94 per cent. of the efficiency of the common wood-burning steam-boiler furnace.

48. The relative efficiency of fuel, comparing wet tan with dry wood, by weight, the former containing between 55 and 60 per cent. of water, becomes $\frac{4{\cdot}24}{4{\cdot}69} \times 100 = 90{\cdot}40$ per cent., each fuel being consumed under the most favorable conditions shown above, and equal weight of ligneous fuel being taken for comparison.

A cord of dry yellow pine, as per experiments of Prof. Johnson, evaporated 12618·3 pounds of water. A cord of wet, spent tan, burned in the Thompson furnace was equivalent to $\frac{9459{\cdot}2}{12618{\cdot}3} = 0{\cdot}75$ cord of dry wood. One cord of wet spent tan burned in the Crockett furnace, was equivalent to $\frac{7103{\cdot}84}{12618{\cdot}3} = 0{\cdot}56$ cord of dry yellow pine.

49. A cord of dry yellow pine is approximately equal in heating power to 0·6 of a ton of coal, and, conversely, the ton of good coal is equal in calorific power to 1·66 cords of soft wood. An average pound of dry wood is theoretically capable of evaporating 6·66 pounds of water from and at 212°. A pound of good anthracite, similarly, should evaporate 13·5 pounds of water.

The "absolute efficiencies" of coal and wood, under the conditions already described in the several cases mentioned, are as follows: coal 70 per cent.; wood—in the Crockett furnace, 66 per cent., in the ordinary steam-boiler furnace, 70 per cent., and in the Thompson furnace, 85 per cent.—reckoning the evaporation of the moisture in the fuel. Excluding this moisture, the percentages become respectively 70, 48, 70 and 64.

THEORY OF FURNACES.

50. The data obtained at these trials are sufficiently complete to furnish a basis upon which to construct the theory of action of each furnace, and to give approximate determinations of quantities which are of importance in that connection, and of interest in their bearing upon practical deductions. The most important points are the temperatures of furnace and of chimney flue, the quantity of air supplied, and the effect of variations of area of heating surface of boilers.

TEMPERATURES OF FURNACE AND OF CHIMNEY FLUE.

51. An approximate determination of the temperature of furnace can be made, in this case, in the following manner:

The fuel used at this furnace, as taken from the leach, contained more than one-half its weight of water. In handling, it lost some of this moisture. When thrown upon the top of the furnace and before it was thrown upon the fire, it, by its non-conducting property, prevented to some extent loss of heat, and such heat as was absorbed by it was usefully employed in evaporating its moisture. The quantity of water thus lost before entering the furnace may be estimated approximately at about one per cent. in handling, and 3 per cent. at the furnace. Box, in his "Treatise on Heat," gives the total loss of temperature by conduction and radiation, in a fire-brick furnace, as 10 per cent. Here, several long ovens were placed side by side, and the principal loss was that from the top. Very little could take place laterally, and no heat could pass downward.

The total loss here may be taken as 2½ per cent., which would so change the composition of the wet fuel as to leave it with 3 per cent. less water, making it about 45 per cent. combustible and 55 per cent. water.

Taking the available heat per pound of the dry portion, at 6480 thermal units, each pound of wet fuel yields 2916 units of heat. Of this, 531·6 are absorbed in the evaporation of the 55 per cent. of water, leaving 2384·4 units to raise the temperature of the products of combustion. Of these there are, as a minimum, 3·7 pounds having a mean specific heat of about 0·287.

The elevation of temperature is therefore 2245·3°, and adding the mean temperature of the atmosphere, 74°, the mean temperature of furnace, assuming no dilution with unused air and no losses, would have been about 2320°. Losing about 2½ per cent., the temperature becomes 2260°.

The temperature of chimney flue was found by experiment to have been 544°. The furnace gases were therefore cooled 2260° — 544° = 1716° by the loss of heat given up to the boiler. This is equivalent to 1716 × 0·287 = 492·5 heat units per pound of gas, and to 4049·4 units per pound of ligneous material in the fuel.

The "equivalent evaporation" from and at 212° is 4049·4 ÷ 966·6 = 4·18 pounds of water. The actual exaporation was equivalent to

4·24 pounds, and the difference—less than one per cent.—represent losses and errors of approximation.

52. The actual existing temperature of furnace can be thus estimated: the available heat per pound of fuel, excluding water, has been given at 2916 thermal units. Of this $\frac{531{\cdot}6}{2916} = 0{\cdot}182$ was not useful in raising the temperature of either the furnace or the chimney. Hence, of all heat liberated, $1{\cdot}00 - 0{\cdot}182 = 0{\cdot}818$* was efficient in elevating the temperature of furnace, and $0{\cdot}37 - 0{\cdot}182 = 0{\cdot}188$ was effective in producing the observed temperature, 544° of chimney. Then, since the same quantity of gas passes at both places, the temperature of furnace was $\left(\frac{0{\cdot}818}{0{\cdot}188} \times 470\right) + 74° = 2118{\cdot}5°$. To this is to be added the slight loss of temperature, *en route* between furnace and chimney, by conduction and radiation.

DETERMINATION OF AIR SUPPLY.

53. The air supply of the Thompson furnace is unusually restricted as has already been noted.

Instead of an ash-pit with a front entirely open, we find here closed ash-pit doors, and no other opening for the passage of air than the comparatively small orifices in the registers with which the doors are fitted. The usual amount of air supplied, in furnaces burning coal, is generally given as about twice the theoretically required quantity, giving a temperature of about 2400°. In exceptional cases, the air supply falls as low as one and a half times the theoretically required amount, the temperature reaching about 3000°. In such cases, it sometimes happens that the grates are melted down, cast-iron melting at between 2700° and 2800°.

In the Thompson furnace, with an ash-pit fire, this is very likely to take place with iron grates, and the inventor was therefore driven to the use of fire-brick grates. The mean temperature of the products of combustion is, however, lower, notwithstanding the restricted air supply, in consequence of the presence of moisture.

The quantity of air supplied is calculated as follows: The difference between the theoretical and the actual temperature of furnace,

* Assuming 6480 units as the heating power of the tan when dried, the efficiency of this furnace becomes 0·63, and 0·37 of the total heat of the fuel passes off by the chimney.

as above estimated, is 2260° — 2118° = 142°, corresponding to 142 × 0·287 = 40·75 thermal units per pound of gas, or 40·75 × 3·7 = 150·8 units per pound wet fuel, and 150·8 ÷ 0·45 = 335·1 units per pound of wood, which heat was distributed through the air diluting the products of combustion.

This latter amount is sufficient to heat (335·1 ÷ 0·238) ÷ 2044 = 0·69 pounds of air from the temperature of the external air 74° to 2118°. The theoretically required quantity of air per pound of wood is 6 pounds; hence the products of combustion at the Thompson furnace were diluted with 12 per cent. of air; this is one-fourth that of ordinary practice with coal fires.

TEMPERATURES IN THE CROCKETT FURNACE.

54. The temperature of chimney flue not being known, the estimates of temperature of furnace and of air supply cannot be so satisfactorily determined for the Crockett furnace. The following may, in the opinion of the writer, be taken as a fair approximation.

The composition of the fuel, in this case, was slightly changed in handling, between the leach and the furnace, as before. Lying in front of the furnace also, a small amount of drying must have occurred by radiated heat. Taking the total amount of both influences as producing an alteration of 2 per cent. in the composition of the fuel, it becomes 52 per cent. water and 48 per cent. dry wood.

55. The theoretical temperature of furnace gases, estimated as before, is reduced largely in this case, by the air of dilution. The fuel was burned at the rate of about 20 pounds per square foot of grate per hour, and the weight of carbon, the only valuable heat-producing element, was 5 pounds per square foot of grate per hour. The bulky character of the fuel compelled the opening of the doors, in charging the furnace, about once in seven or eight minutes. The fire burned somewhat irregularly into holes, allowing an unusual amount of air to pass up unutilized.

In ordinary practice, with anthracite coal fires, the fuel burns, with such draught as was found at the Crockett furnace, at the rate of about 10 pounds carbon per square foot of grate per hour. The doors are opened about once in fifteen or twenty minutes, and the air supply is about 240 pounds per square foot of grate surface per hour.

56. The air supply at the Crockett furnace was apparently in excess of that just given, by a large amount. Neglecting this ex-

cess, and calculating the temperature of the furnace as if the air supply were the same as with coal, the following results are obtained:

Available heat per pound wet tan, . .	3110·4 units.
Rendered latent by evaporating 52 per cent. water,	503·6 "
Effective in elevating temperature, . . .	2606·8 "

This was distributed through 12·5 pounds of gaseous products of combustion, of a mean specific heat, 0·25. The elevation of temperature was therefore 832·8°, and adding the mean temperature of external air, we obtain for the average temperature of gases escaping from the furnace, including cold air streaming through the furnace doors and the holes in the fire, 919·3°, or about 100° above the temperature at which combustible gases can take fire.

Taking the air supply as possibly, at times, as low as that considered the minimum with ordinary coal fires, 180 pounds per square foot of grate per hour, where burning fuel with sluggish draught, the temperature of furnace at such times becomes 1150·3°.

57. The temperature of chimney flue may be readily estimated for these conditions. Referring the performance of this furnace, like the preceding, to "dry wood" as a standard, its efficiency is 47 per cent. Hence 53 per cent. of the heat obtainable from the fuel passes off by the chimney. The loss of heat by the escape of unburned carbon in the form of smoke, although more than at the other furnace, was not probably sufficient to be here taken into account. The following are the estimates:

Available heat per pound of wet tan, . .	3110·4 units.
Passing up chimney, 53 per cent., . .	1648·5 "
" " latent in vapor, . .	503·6 "
" " elevating temperature, .	1144·9 "

This was distributed throughout 12·52 pounds of gas, where the usual supply of air was maintained, and through 9·64 pounds in the case of less free supply, supposed possible at times.

The heat per pound of gas amounts to 91·4 units for the first case, elevating the temperature $91{\cdot}4 \div 0{\cdot}25 = 365{\cdot}6°$ above that of the atmosphere, or to 452°.

Under the other supposed conditions, the elevation of temperature of chimney becomes 467·7°.

To secure an economy at this furnace equal to that obtained at the Thompson furnace, it would be necessary to reduce the quantity of heat carried off by the chimney gases, in the proportion of 53 to 37.

One-third of this heat is latent in the vapor of water, and no part of that can be secured. The requisite reduction of temperature of gases to effect this economy is thus exaggerated; and it would be necessary, were such a thing possible, to bring down the temperature of chimney to between 140° and 160°, to a temperature 160° or 140° below that of the boiler itself, or to less than one-fourth that required for most efficient draught.

EFFICIENCY OF FURNACES.

58. In determining the precise value of two competing sets of apparatus, as generators of heat, it is necessary first to obtain from each its best performance in producing heat, and then to provide means of absorbing and utilizing that heat with equal thoroughness in both cases.

The proper area of heating surface of boilers will therefore vary with each case. The same area, where the furnaces themselves differ considerably, may, in the one case, allow a waste of heat, while in the other it may reduce the temperature of gases so far as to compel the adoption of a "mechanical draught." In the cases here considered, the area of heating surface was fortunately very nicely adapted in each instance to the requirements of the case. In both examples, the temperature of chimney flue is found to be somewhat below that required for most efficient draught; but was not far different in the two cases, the less economical furnace having the economical advantage of such difference as did exist.

The trial, therefore, exhibits very fairly the intrinsic values of these two furnaces as heat-generating apparatus, and of these two radically different methods of working them, as taken apart from the efficiency of heat absorbing or heat utilizing contrivances.

59. The importance of high temperature of furnace is strikingly and beautifully illustrated by these results. The two furnaces develop practically the same amount of heat from the fuel, but the one distributes it through a large volume of gases at low temperature, sending a considerable proportion of it up the chimney, while the other raises a small volume of gas to a much higher temperature, making it more available to the extent of 33 per cent., and finally, even then sending up the chimney gases of higher temperature than the first.

The abstract *efficiency of the furnace* in any ordinary case is represented by the formulas—

$$\mathfrak{E}' = \frac{\tau_1 - \tau_2}{\tau_3 - \tau_1} = \frac{T_1 - T_2}{T_1 - T_3}$$

Where $\mathfrak{E}'$ represents the efficiency and τ_1 and τ_2 are the absolute temperatures at which the heat is generated, and at which wasted heat is discharged, and τ_3 that of the external air, T_1, T_2, T_3, are temperatures on the Fahrenheit scale.

In these cases $$\mathfrak{E}' = \frac{2118° - 544°\text{F.}}{2118° - 74} = 0{\cdot}77.$$

$$\mathfrak{E}'' = \frac{919° - 452°}{919° - 86.5} = 0\ 56.$$

60. These values do not represent the *efficiency of the fuel*, including the vaporization of water contained within itself. In these cases the heat lost, as latent in vaporization, before the generation of these temperatures, is to be deducted to give the total efficiencies of the fuel, which thus are found to have the values $0{\cdot}77\ (1 - 0{\cdot}182) = 0{\cdot}63$ and $0{\cdot}56\ (1 - 0{\cdot}175) = 0{\cdot}46$.

The experimental determinations were 0·64 and 0·48, if referred to seasoned wood, and 0·63 and 0·47 when referred, as here, to dry wood of a calorific value of 6480 heat units.

To make the values of $\mathfrak{E}$ comparable with the standard already assumed for *final absolute efficiency*, per experiment, it is necessary to add 9 per cent. to the first values of $\mathfrak{E}$, in each case, in order to credit the fuel with the heat used in the vaporization of its water, and with the heat carried by the vapor up the chimney.

Thus the values $0{\cdot}77 + 0{\cdot}09 = 0{\cdot}86$, and $0{\cdot}56 + 0{\cdot}09 = 0{\cdot}65$ are deduced. These ratios, by experimental determination, were 0·86 and 0·67. The correspondence of these figures with those just deduced theoretically, is a remarkably conclusive evidence of the accuracy of the estimated temperature and of the fact that the difference of efficiency found by trial is due to such difference of temperature. The accordance is unusually precise.

EFFECTS OF AREA OF HEATING SURFACE.

61. Rankine has given a formula* for determining the efficiency of fuel in ordinary steam boiler practice, where the ratio of the area of heating surface, and of fuel burned per hour, to the square foot of grate surface, is known:—

$$\frac{E'}{E} = \frac{B\,S}{S + A\,F},$$

in which $\frac{E'}{E}$ is the quantity called above $\mathfrak{E}'$, A and B are constants,

*Steam Engines and Prime Movers, p. 292, § IV.

and F and S are the ratio of fuel burned per hour to the square foot of grate, and the ratio of area of heating surface to grate area.

For the cases here considered, $A = 0{\cdot}5$, and $B = 0{\cdot}92$, $S = 8{\cdot}5$ for the Thompson, and 14·5 for the Crockett furnace, $F = 1{\cdot}38$, and 5·3; $\frac{F}{S}$ becomes 0·13 and 0·36, and the value of $\frac{E'}{E}$ is, for the Thompson 0·859, and for the Crockett furnace 0·776.

Were this formula applicable to these cases, the experimental determinations of efficiency should coincide with these, but they are 0·64 and 0·48. This difference is a consequence of the facts that the fuel used in these furnaces was wet, and that the large proportion of heat absorbed by the water was so much abstracted from the efficiency of the fuel. Thus the absolute values are reduced.

They differ, also, in consequence of the important fact exhibited in the preceding paragraphs, that the temperature of furnace differs in each case (and in the case of the Crockett furnace immensely), from the temperature, 2400°, given by Rankine as the mean temperature of furnaces to which his formula is adapted. This changes relative values.

The value 0·859, for the Thompson furnace, is almost precisely that obtained by experiment—"including water in fuel," 0·86—as it should be, since the temperature of that furnace, 2118°, is not far different from that of the ordinary coal fire. The value, 0·776, for the Crockett furnace differs greatly from that formed by experiment—"including water in fuel," 0·67—as would be expected in consequence of the exceptionally low temperature of that furnace.

The difference between these two theoretical values, $0{\cdot}859 - 0\ 776 = 0{\cdot}083$, would represent approximately the loss of total absolute efficiency that might be expected, were the case one of ordinary practice, and were the Thompson furnace supplied with boilers of as small a ratio of heating surface to fuel consumed, $\frac{F}{S}$ as the Crockett furnace actually had.

The difference which would readily be produced would be less in consequence of a circumstance, peculiar to that example, of which the influence has not been noticed by writers on this branch of the theory of engineering.

62. The rate of conduction of heat from the furnace gases to the heating surfaces with which they are in contact varies, in some not

well determined ratio, with the difference of temperature. It may be represented approximately, according to experiments of Charles Wye Williams,* and judging from the analysis of M. Paul Havrez,† by a hyperbolic curve, of which the equation is $x\,y = A$, y representing the evaporation for a unit of area of a tube at a distance x from the furnace.

$$U = B \log x$$

is the equation of total evaporation.

When the volume of gas is the same, as in cases to which the formula of Rankine applies, the constants in these equations are the same, and his formula gives a remarkably satisfactory approximation. Where, as in the Thompson furnace, the restriction of the air supply causes a comparatively slow movement of gases along the heating surface, the value of that portion nearest the fire becomes enhanced, leaving the furthest portions of less efficiency.

The effect of reducing the air supply nearly one-half would, therefore, be to actually reduce greatly the amount of the theoretical loss, 0·08, just given. The real loss would be somewhere between this 8 per cent. and the smaller differences noticed between the theoretical estimates of efficiency of fuel and the actual differences shown by experiment. This latter consideration may, perhaps, be taken as a proof that this difference of efficiency due to such a change of heating surface, would amount approximately to 2 per cent. Were more steam wanted, this would be at once sacrificed at the Thompson furnace, to bring the temperature of chimney up to that, 645°, which would give most efficient draught.

63. At the Crockett furnace, the effect of the exceptionally low temperature of furnace is to equalize the value of heating surface; and the considerable velocity of the gaseous current, which is a consequence of the unusually great volume of air passing through the furnace, increases this effect. The nearer surface is inefficient, and the most distant portions of the heating surface are therefore proportionally much more efficient than in the preceding case.

Extension of surface is, however, precluded by the fact that the temperature of escaping gases would fall still further below that re-

* "On the Steam Generating Power of Marine and Locomotive Boilers."—London, 1864.

† "Evaporisation decroissante en Progression Geometrique dans les Chaudieres."—Revue Industrielle, 1874.

quired for effective draught, and, as already indicated, were it possible to operate the furnace at all, this temperature would become one-half the temperature of the boiler, were so much heat abstracted as to give an efficiency of fuel equal to that obtained in the other furnace. Heat would then pass from the boiler to the gas at those portions of its surface farthest from the fire, and the draught could only be maintained by means of special "blowing" apparatus. This is another fact illustrating the importance of high temperature of furnace in the attainment of high furnace efficiency.

64. The table given on the following page presents the results of the above investigation in a concise form, in which it may be found very useful for reference.

65. Both of these furnaces were introduced about twenty years ago, and the first is in somewhat extensive use. No experimental determination of their actual relative efficiencies has ever been made before, so far as the writer is aware which has enabled their theory to be worked out. The determination of their theory, as here given, has greatly interested him, and will, perhaps, prove as interesting to the profession. It may be found of value, in view of the many important applications which are daily being made of the various kinds of wet fuel.

The temperatures, as given, may be somewhat below actual temperatures where they are determined from the composition of fuel, as the calculations are made on the assumption that all vapors issuing from the fuel are raised to the mean temperature estimated. The real fact is, that they are expelled while the temperature of issuing gases is reduced by their presence, and they therefore do not abstract as much heat as is debited to them in the calculation.

During those intervals of time which elapse between the drying of one charge and the introduction of the next, the temperature of furnace rises to that due to the combustion of dry fuel. The results, as given, are probably, however, practically and sufficiently correct.

RESULTS OF TRIALS OF FURNACES BURNING WET SPENT TAN BARK, AUGUST, 1874.

KIND OF FURNACE.	Fuel.	Percentage	Total weights pounds.			Percentages		British thermal units per cord of tan	Apparent evaporation.			Actual evaporation.	Ratio of air supply to theoretical.
		Water.	Combustible.	Fuel.	Combustible.	Feed.	Steam. Priming	Priming to feed.	Priming to steam.		Per cord fuel.	Per pound combustible.	Per sq. ft. grate per hour.	Per sq. ft. heat surf. per hour.	Per lb. of fuel.	Per lb. combustible.	
Thompson.	Tan.....	59	41	44945	17198·41	73125	68393·8	4731·2	6·47	6·92	9143221·4	9590·75	4·25	23·7	2·81	1·3	3·08	1·12
Crockett..	Tan.....	55	45	22336	10051·20	28609	24774·32	3734·68	13·1	15·	6866576·75	6335·83	2·83	65·9	4·62	.....	2·46	8·
Ordinary st'm boiler	Pine wood.	50	50	.....	2950·50	.....	.....	.....	.....	.....	.....	10891·25	4·05	61·5	2·29	4·05	4·03	.....
Ordinary st'm boiler	Anthracite Coal.....	91	9	.....	.....	.....	.....	.....	.....	6	.....	.....	8·75	95·	3·00	7·35	8·75	2·

KIND OF FURNACE.	Approximate estimate mean temperature of furnace gas, Fahrenheit.		Equivalent evaporation per 212° F. per lb., including water in fuel.	Equivalent evaporation from 212° F. per lb., excluding water in fuel.	Relative efficiency excluding water in fuel—Crockett = 1.	Relative efficiency excluding water in fuel—wood = 1.	Relative efficiency including in account water in fuel-Crockett = 1.	Relative efficiency including water in fuel—wood = 1.	Absolute efficiencies, water in the fuel excluded		Absolute efficiencies, water in the fuel included, dry wood as stand'd	
	Furnace	Flue.							Standard of 6385 units.	Dry wood of 6480 units.	of 6385 units.	of 6480 units.
Thompson.....	2118°	544°	5·68	4·24	1 33	0·90	1·29	1·21	0·64	0·63	0·85	0·86
Crockett.....	919°	452°	4·41	3 19	1·00	0·68	1·00	0·94	0·48	0·47	0·66	0·67
Ordinary steam boiler.....	.....	.....	4·60	4·60	1·47	1·00	1·06	1·00	0·70	0·70	0·70	0·70
Ordinary steam boiler.....	2400°	700°	10·60	10·60	3·28	2·23	2·37	2·23	0·70	0·70	0·70	0·70

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxix, page 69.]

The principle of the improvement is now complete so far as concerns the relative movement of the hammer drop and the valve, but there must be some principle applied for the extraneous movement of this added mechanism. Looking around for examples, we can see that where movement continues after the force which produced it has ceased to act, the principle is in nearly every case that of momentum. We see cannon balls travel for miles, the impelling force acting for a few feet only, or the weaver's shuttle performing its flight after the driver has stopped its movement, and it may be safely assumed in this case that momentum is the available force to produce this independent movement required in the valve gearing.

To sum up, it has been determined by inductive reasoning coupled with some knowledge of mechanics, that a steam hammer, to give a dead blow, requires the following conditions in the valve gearing:

First. That the drop and valve, while they must act relatively, cannot move in the same time, or in direct unison.

Second. The connection between the hammer drop and valve cannot be positive, but must be broken during the descent of the drop.

Third. The valve must move after the hammer stops.

Fourth. To cause a movement of the valve after the hammer stops there must be an intermediate agent, that will continue to act after the movement of the hammer drop has ceased.

Fifth. The obvious means of attaining this independent movement of the valve gear is by the momentum of some part set in motion by the descent of the hammer.

The invention is now complete, and as the principles are all within the scope of practical mechanism, there is nothing left to do but to devise such mechanical expedients as will carry out the principles laid down. This mechanical scheming is a second and in some sense an independent part of machine improvement, and should always be subservient to principles; in fact, to have it precede principles, constitutes chance invention or chance scheming. That it is to be re-

garded in a sense distinct from dealing with mechanical principles, is evident from the fact that a man may have this faculty of mechanical scheming developed in an extraordinary manner, and yet be comparatively ignorant of the principles of mechanism.

Referring again to the hammer problem, the apprentice will find by examining the subject that the builders of automatic acting steam hammers that are capable of giving the dead stamp blow, have employed the principles that have been described, with perhaps the single exception of Messrs. Schwartzkopf, German engineers, who, instead of employing the momentum of moving parts to open the valve after the hammer stops, depend upon disengaging valve gear by the concussion and jar of the blow, the valve gear by its gravity opening the valve. The eminence of German engineers in this particular branch of mechanical engineering is, however, such that they have no doubt adopted various devices besides the one just described.

I will not consume space to describe the converse of this logical system of inventing, nor to picture a chance schemer hunting after mechanical expedients to accomplish the valve movement in the example that has been given. The reader can do this for himself, and no doubt has done so as he went along.

Inventions in machine improvement, no matter what their nature, must of course consist in and conform to certain fixed principles, and no plan of urging the truth of a proposition is so common, even with the chance inventor, as to trace out the principles that govern his discovery. This is hence a negative course, useful in its place, to confirm and further explain what may have been demonstrated by accident, but the true plan is to proceed in the other direction, from principles to practice, the course that is here recommended to the apprentice in his attempts to invent.

In studying improvements with a view to practical gain, the learner can have no reasonable hope of accomplishing much in fields already gone over by able engineers, nor in demonstrating anything new in what we may call exhausted subjects, such as steam engines or water wheels; but should choose rather new and special subjects, and above all things avoid radical innovations upon existing views or existing practice.

It has been already remarked that the boldness of young engineers is very apt to be inversely as their experience, not to say their want of knowledge, and it is only by a strong and determined effort

towards conservatism, that a true balance is maintained in judging of new schemes.

I will end this article by citing the reader to some examples illustrating the general plans that have been briefly laid down in regard to inventions.

The life of George Stephenson, if studied, will prove that notwithstanding the novelty and great importance of his improvements in steam transit, he did not "discover" these improvements. He did not discover that a floating embankment would carry a railway across Chat Moss, neither did he discover that the friction between the wheels of a locomotive and the rails would enable tractive power to draw a train. Everything connected with his history shows that all of his deductions were founded upon a method of reasoning from principles inductively, and to say that he "discovered" our railway system, according to the ordinary construction of the term, would be to detract from his hard and well-earned reputation and place him among a class of fortunate schemers who can claim no place in the history of legitimate engineering.

Count Rumford did not chance upon the new philosophy of forces upon which the whole science of dynamics now rests; he set out upon a methodical plan to demonstrate conceptions that were already matured in his mind, and to verify principles which he had assumed by deductive reasoning; in fact, all great and substantial improvements that have performed any considerable part in developing modern mechanics, have come through this natural course of first dealing with primary principles, instead of groping about blindly after mechanical expedients.

WORK SHOP EXPERIENCE.

I have now reached that part of this article that may be of most interest and perhaps of most use to the engineering apprentice, especially those who are not able to avail themselves of the advantages of a course in the draughting and pattern department, or in the commercial department of the works where they may be engaged.

To argue the necessity of learning practical fitting as a part of an engineering education would be superfluous. The mechanical engineer that has not been "through the shop" can never expect to attain success, nor command the respect even of the most inferior workmen, and without this power of influencing others, he is neither

fitted to direct construction, nor to manage details of any kind connected with engineering industry, nor even to keep records.

There is nothing that more provokes a feeling of resentment in the mind of a skilled man than to meet with those who have qualified themselves in the theoretical and commercial details of engineering work, and then attempt to direct the labor which they do not understand; nor is a skilled man long in detecting an engineer of this class; a dozen words in conversation upon any mechanical subject is generally enough to furnish a clue to the amount of practical knowledge possessed by the speaker.

The reasons for a shop course are many; the main one, perhaps, being to learn the nature of fitting operations which must continually modify the plans of construction, and determine cost. As remarked in a previous place, no one can prepare successful designs for machinery, who does not understand the details of its construction; he should know how each piece is moulded, forged, turned, planed or bored, and the relative cost of these processes by the different plans that may present themselves to his mind.

The influence over workmen and under-managers is always dependent upon the practical knowledge of the person in general charge. An engineer may direct and control a work without a knowledge of practical fitting, but such control is merely a commercial one and cannot of course extend to mechanical details which are generally the vital part; and the obedience that may be enforced is not to be confounded with the respect that superior knowledge always commands.

Another gain from learning practical fitting is the confidence that such knowledge inspires in either the direction of work or the preparation of plans for machinery. The man who hesitates in his plans for fear of criticism, or who does not feel a perfect confidence in his own deductions, will never achieve much success. It requires not only the highest powers of the mind to generate plans for machinery and to direct construction successfully, but also requires that the mind be unfettered by the restraints that have been indicated.

The changes that have totally revolutionized machine fitting during thirty years past, have been of a character to dispense with hand skill, and supplant it with what may be termed mental skill. The mere physical effect that may be produced with a man's hands, has steadily diminished in value until now it has almost come to be reckoned in foot pounds. The same remark applies in some degree to

hand skill, which now holds a place quite different from what it did even twenty years ago.

Once the apprentice entered the shop to learn a certain amount of hand skill, and to acquaint himself with a number of mysterious processes, and to learn a series of arbitrary rules which might place him at a disadvantage even with those whose mental capacity was inferior and who had less education; but now the whole is changed. An engineering apprentice enters the shop with a confidence that he may learn whatever the facilities afford, if he will put forth the mental effort needed, and that there are no mysteries to be learned which are not reached and explained by the physical sciences. In short, to learn machine fitting at the present time is but a small matter compared with twenty years ago, provided the learner sets out properly prepared and with intelligent views of what he is to undertake.

This change in engineering pursuits has also produced a change in the workmen almost as thorough as that in the manipulation. A man who deals with special knowledge and feels that the secrets of his calling are not governed by general rules, that may qualify others without his assistance, is always more or less narrow-minded and ignorant. The nature of his relations to others makes him so; of this no better proof is wanted than to contrast the intelligence of workmen who are engaged in exclusive callings, with those whose pursuits are regulated by general rules and principles. The machinist of modern times, at least in the more enlightened countries, having outgrown what we may term mechanical superstition, has thereby been raised to a social position that is confessedly superior to that of other mechanics, so that shop associations that were once so dreaded by those who would otherwise have become mechanics, are no longer an obstacle.

With this much in a preliminary way I will now notice some matters connected with apprentice experience in the workshop, endeavoring to select such as may be of most value to a learner.

When you enter the shop the first thing to be done is to gain both the confidence and the respect of the manager or foreman who has charge of your work, and remember that to gain this confidence and respect is different from and has nothing to do with your social relations. To inspire the confidence of a friend you must be kind, faithful and honorable, but to command the confidence of a foreman you must be punctual, diligent and intelligent. There is no more kindly

sentiments of regard than those that may be founded in this way, and altogether independent of what is popularly considered as the incentives to such a relation. You may have the misfortune to break tools, spoil your work, and fail in every way to satisfy yourself, yet if you are punctual, diligent, and manifest an interest in the work, these misfortunes will not call out the resentment of those around you.

It must always be remembered that what is to be learned is not in the shop to be estimated according to your own conceptions of its importance. A manager and the men around look upon fitting as one of the most honorable and intelligent of pursuits, and deserving of the esteem and highest efforts of an apprentice; and while the learner may not think it a serious thing to make a bad fit, or to meet with an accident, his estimate is not the one to judge by, and the least word or act that will lead workmen to think that an apprentice is indifferent, from that moment will destroy their interest in him and cut off one of the main sources from which his knowledge is to be derived.

An apprentice should in entering the workshop avoid everything that flavors of fastidiousness, either of manner or of dress; nothing is more repulsive to workmen, and it may be added, nothing is more out of place in a machine shop. An effort to keep as clean as the nature of the work will admit of, is at all times right, but to dress in clothing that is not appropriate, or to allow an aversion to grease to interfere with the performance of work, is sure to provoke derision.

The art of keeping reasonably clean even in the machine shop is worth studying; some men are greased from head to foot in a few hours, no matter what their work may be; while others, except their hands and an apron, will keep clean and perform the same work without sacrificing their convenience in the least.

This is the result of habits that are easily acquired and easily retained, which may become of great use, as well as tend to an economy of clothing, and a neatness of appearance that will convey an impression of neat work.

Be punctual; it costs nothing, and buys a great deal. The learner who reaches the shop a quarter of an hour before starting time, and spends the time in looking about, not only manifests an interest in his work, but avails himself of an important privilege, and one of the most effectual in gaining shop knowledge. Ten minutes spent in

walking about noting the changes wrought in the work from day to day furnishes constant material for thought, and acquaints a learner with many things which he would not otherwise observe. It requires, however, no little care and discrimination to avoid a kind of resentment that any workman feels in having his work examined, especially when he has met with an accident or made a mistake, and when he thinks that the inspection is prompted by curiosity alone. The better plan in such cases is to ask permission in a way that no one will hear it except the person addressed, the application of which will always secure both courtesy and explanation.

Politeness is as indispensable to a learner in a machine shop as it is to a gentleman in society; no matter who the men may be that are to be dealt with, courtesy is not only their due, but the policy for the learner. The character of the courtesy may be modified to suit the person, but still it must be courtesy. The apprentice may understand differential calculus, but a workman may understand how to bore a steam cylinder, and in his estimation the two things are equal, and if he should gain an advantage in politeness, the apprentice is placed at a disadvantage. A man is coarse indeed when he is not influenced by courtesy that is not affected nor overdone.

Questions and answers constitute the greatest means of acquiring technical information, and the engineering apprentice should carefully study the true principles of questions and answers, just as he does the principles of machinery. Without the art of questioning but slow progress will be made in learning shop manipulation, and improper questions will soon lose all the advantages that might be gained.

A proper question is one that the person asked will understand, and the answer be understood when it is given; not an easy rule, but a correct one. The main point is to consider questions before they are asked; let them be relevant to the work in hand, and not too many. To ask frequent questions, is to convey an impression that the answers are not considered, an inference that is certainly a fair one, if the questions relate to a subject that demands attention. If a man is asked one minute what diametrical pitch means, and the next minute how much cast iron shrinks in cooling, he is very apt to be disgusted, and think the second question not worth answering.

It is important, in asking questions, to consider the mood and present occupation of the workman addressed; one question asked

when a man's mind is not occupied, and when he is in a communicative humor, is worth a dozen questions asked when he is engaged, and when he is not disposed to talk.

It is a matter of courtesy in the usages of the shop, and one of expediency with the learner to ask questions from those who are presumed to be best informed on the subject to which the questions relate, and it is equally a matter of courtesy to ask questions of different workmen, being careful, however, never to ask two different persons the same question, nor questions that may call out conflicting answers.

There is not a more generous or kindly feeling in the world than that with which a skilled mechanic will share his knowledge with those who have gained his esteem, and who, he feels, both merit and desire the aid that he can give.

An excellent plan to retain what is learned, is to make notes, not to attempt to store up a book of notes for reference which would not only be of no value but would hinder the memory, but to make notes that may be referred to a few times and to assist in fixing facts in the mind. There is nothing that will assist the memory more in learning mechanics than to write down facts as they are learned, even if the memorandum is never again referred to.

I do not intend to recommend writing down rules, tables that may apply to shop manipulation, but facts that require remark or comment which will not only assist in committing such facts to memory, but will cultivate the power of making technical descriptions, which is a necessary part of an engineering education. Specifications for engineering work are the most difficult of composition; they may be long, tedious and irrelevant, or concise and lucid. There are also a large number of conventional phrases and endless technicalities that must be learned, and to write them will not only assist in committing them to memory, but will determine their orthography.

In making notes, as much as possible of what is written should be condensed into brief formulas, a form of expression that is fast becoming the written language of the machine shop. Reading formulas is in a great degree a matter of habit, like studying mechanical drawings, which, at the beginning, are a maze of complexity, and after a time become intelligible and clear at a glance.

Upon entering the shop, the learner will generally, to use a shop phrase, be introduced to a cold-chisel and a hammer, and he will, per-

haps, regard these hand tools with a kind of contempt. Seeing other operations carried on by power, and the machines in charge of skilled men, he is too apt to esteem chipping and filing as of but little importance, and mainly to keep apprentices employed. Let the apprentice be assured that long after, when a score of years has been added to his experience, the file will still remain the most crucial test of his hand skill, and that after learning to manipulate power-tools of all kinds in the most thorough manner, a few blows with a chipping-hammer, or a half dozen strokes with a file, will not only be a harder test of skill, but the one that he is most likely to meet with.

To learn to chip and file is indispensable, if for no other purpose, to be able to judge of the proficiency of others or to instruct them. Chipping and filing are purely matters of hand-skill that are tedious to learn, but when once acquired, are never forgotten. The action of a file is an interesting problem to study, and one of no little intricacy, as the learner will find when he considers it; in filing across a surface one inch wide, with a file twelve inches long, the varying pressure that is required at each end of the file to guide it level, seems to be beyond the attainment of the hands and beyond the nice sense of feeling that determines this varying pressure. It is quite a problem even if there is a constant length of stroke assumed, but when we consider that the stroke is continually changed, the length of the files and the breadth of the surface also, it is a wonder indeed that true surfaces can be made with a file, or even that a file can be used at all. The fact is, it takes years of experience to file well, and requires also a special faculty which every one does not possess.

In filing, the files should be kept clean, each one laid in order, with a strip of wood under the ends, to prevent them from rolling and to keep them out of the dirt. Each file should have its handle well fitted and to stand true with the blade. The learner has continually to contend with an inclination to use his smooth and dead smooth files before the work is finished, and to think more of the finish on surfaces than their truth.

If asked for advice as to the most important object for an apprentice to aim at in beginning his fitting course, nine out of ten experienced men would say, "to do work well." As power is measured by force and velocity, work is measured by the two conditions of skill and time. The first consideration being, how well a thing may be done, and secondly, in how short a time may it be performed. The

skill spent on a piece of work is the measure of its worth; if work is badly executed, it makes no difference how short the time of performing the task, this can add nothing to its value.

The learner is very apt to reverse this proposition at the beginning, and place the time before the skill, but if he will note what he sees around him it will at once appear that the first criticism is always directed to the character of the work performed. A manager does not ask a workman how long a time was consumed in preparing a piece of work until its character has been passed upon; in short, the quality of work is its mechanical standard, and the time consumed in preparing work is the commercial standard, applied, of course, to work that is good and competent, for if an article is spoiled there is no need of proceeding to the second standard to judge it by. A job is never properly done when the workman can see faults in it, and in machine fitting, as a rule, the best skill that can be applied is no more than the conditions call for, so that the first thing to be learned is to perform work well, and afterwards to perform it rapidly.

Good fitting is not so much a question of skill as of a standard that the workman has fixed in his mind, and to which all that he does will conform. If this standard is one of exactness and precision, all that is performed, whether it be filing, turning, planing or drafting, must come to this standard. This faculty of mind I can define no further than to say that it is an aversion to whatever is imperfect and a love for what is exact and precise, and I must add that there is no faculty of the mind that has so much to do with success in mechanical pursuits, nor is there any trait that is more susceptible of cultivation. Exactness and methodical reasoning are the powers that lead to proficiency in engineering pursuits.

There is, perhaps, no more fitting conclusion to these suggestions for apprentices than a word about health and strength. It was remarked in connection with the subject of drafting that the powers of a mechanical engineer were to be measured by multiplying his education and mental abilities into his vitality and physical strength, a proposition which it will be well for the apprentice to keep in mind, for he will certainly meet with its proof, if not in his own case, in that of others.

An apprentice who is not accustomed to manual labor will after commencing find his limbs aching, his hands sore, and will feel exhausted both at the beginning and at the end of the day's work.

These are not dangerous symptoms. He has only to wait until his system is built up so as to sustain this new draught upon its resources and until nature furnishes a power of endurance which will in the end be a source of pride and add a score of years to his life. Have plenty of sleep, plenty of plain substantial food, keep the skin clean and active, laugh at privations, and cultivate a spirit of self-sacrifice and a pride in endurance that will court the hardest and longest jobs.

An apprentice that has not the spirit and firmness to endure physical labor, and to adapt himself to the conditions of the workshop, should select some pursuit of a less aggressive nature than mechanical engineering.

THE END.

ON THE EFFICIENCY OF BELTS OR STRAPS AS COMMUNICATORS OF WORK.*

By Professor Osborne Reynolds.

It has often been remarked that it seems to be impossible so to construct belts that they shall drive without slipping. I am not aware that any reason has ever been given for this; but, on the other hand, most writers seem to have assumed that if the belt is made sufficiently tight, so that the tension on the slack side is from one-half to one-quarter that on the tight side, according as the strap is in contact with one-half or the whole of the pulleys, it will not slip. The object of this communication is to show that not only is a reason to be given for this residual slipping, but that it follows a definite law, depending on the elasticity of the strap, and independent of its tightness over and above what is necessary to prevent it slipping bodily round the wheel.

When a pulley, A, is connected with another pulley, B, by a belt so that A drives B, it is usual to assume that the surfaces of the two pulleys move with the same velocity, namely, the velocity of the strap; and that the work communicated from A to B equals this velocity multiplied by the difference in the tension on the two sides of the belt.

* Reprinted from the London *Engineer*.

This law would doubtless be true if the strap were inelastic, and did not stretch at all under the tension to which it is subjected; but as all straps are more or less elastic, it can be shown that this law does not hold rigorously, although with such an inelastic material as leather it is not far from the truth.

Owing to its elasticity, the tight side of the belt will be more stretched than the slack or slacker side, and will, in consequence, have to move faster. This is easily seen when we consider that each point on the strap completes its entire circuit in the same time, so that if at any instant a number of marks were made on the strap at different points, these marks would all return to the same points in precisely the same time; for the velocity at each point would be equal to the length of strap which passes that point, and on the tight side this would be the stretched length, whereas on the other side it would be the unstretched length, and hence the two sides of the strap would move with different velocities, according to the degree in which the strap is more stretched on the one side than on the other.

Now the stretching of a strap will be proportional to tension, although the degree will depend on its size and the material of which the strap is composed. Let $\lambda\,\tau$ represent the increase in length per foot in a certain strap, caused by a tension of τ lbs. Then, if τ_1 and τ_2 represent the tension on the two sides of the belt respectively, the stretching on these two sides will be respectively proportioned to $\lambda\,\tau_1$ and $\lambda\,\tau_2$, and the difference will be proportional to $\lambda\,(\tau_1 - \tau_2)$. Therefore the velocities of the two sides will be in the ratio $= \frac{1 + \lambda\,(\tau_1 - \tau_2)}{1}$.

Again, it is easy to see that the velocity of the tight side of the strap must be equal to that of the surface of the pulley A which drives it; whereas the velocity of the pulley B, which is driven by the strap, will be the same as that of the slack side of the strap; and hence the velocities of the two pulleys differ in the ratio $\frac{1 + \lambda\,(\tau_1 - \tau_2)}{1}$.

And since the turning effort of the strap on either pulley is the same, namely, $\tau_1 - \tau_2$, the difference of its tensions, the work done by A, which equals its velocity into this effort, will be greater than that taken up by B in the ratio $\frac{1 + \lambda\,(\tau_1 - \tau_2)}{1}$. This excess of work will have been spent in the slipping, or more properly the creeping, of

the strap round the pulleys. The manner in which this creeping takes place is easily seen, as follows: The strap comes on to A tight and stretched, and leaves it unstretched. It has therefore contracted while on the pulley. This contraction takes place gradually from the point at which it comes on to that at which it leaves, and the result is that the strap is continually slipping over the pulley to the point at which it first comes on. In the same way with B; the strap comes on unstretched and leaves it stretched, and has expanded while on the wheel, which expansion takes place gradually from the point at which the strap comes on until it leaves.

The proportion which the slipping bears to the whole distance traveled by the strap $= \lambda (\tau_1 - \tau_2)$, which, as previously shown, is the proportion which the work lost bears to the whole work done by A. From this it appears that the slipping and work lost are proportional to λ, *i. e.*, to the increase which a tension of 1 lb. would cost in 1 ft. length of the strap; and hence, the more inelastic the material is, the better it is suited for belts.

The actual amount of this slipping may be calculated when we know the elasticity of the belts. With leather it is very small. One belt, which had been in use about two years, and was 1·25 in. wide and 3-16 in. thick—the usual thickness—increased in length by sixteen-thousandths under a tension of 100 lbs. From this example it appears that, for a leather belt of breadth b in.:

$$\lambda = \frac{20}{100{,}000} \frac{1}{b}$$

Hence, the ratio of slipping $= \cdot 0002 \frac{1}{b} (\tau_1 - \tau_2)$; and in practice $\tau_1 - \tau_2$ varies from 20 lbs. to 60 lbs. per inch width of belt; therefore the slipping $= \cdot 008$, or nearly 1 per cent. With new straps it would probably be more. With soft, elastic materials, such as india-rubber, the slipping is very much greater. In some instances I have been able to make the driving pulley A turn twice as fast as the pulley B, simply in virtue of this expanding and contracting on the pulleys. This shows at once how it is that elastic straps, such as can be made of soft india-rubber, have never come into use—a fact which is otherwise somewhat astonishing, considering for how many purposes an elastic connection of this sort would be useful. A similar explanation to the above may also be given for the friction occurring

when elastic tires are used for the wheels of carriages and engines. The tire is perpetually expanding between the wheel and the ground. As the wheel rolls on to the tire, it is continually elongating the part between it and the ground which is in front of the point in which the pressure is greatest. This elongation can only be accomplished by sliding the tire over both the surface of the wheel and the ground against whatever friction there may be; and similarly, towards the back of the wheel, the tire is contracting also against friction. Even when there is no tire, if either the wheel or the ground is elastic a similar action takes place; and hence we may probably explain what is usually called rolling friction, which has been observed to take place, no matter how true or hard the surface of the wheel and the plane on which it rolls may be. *Owens College, Manchester, Nov.* 20, 1874.

Development of Magnetism in the Rails of Railways.—M. Heyl, engineer of one of the German railways, in a recent report upon the special section under his charge, calls attention to the development of magnetism in the rails. He says: I have observed that all the rails are transformed at their extremities, after they have been placed in position a few days, into powerful magnets, capable of attracting and of retaining a key or even a heavier piece of metallic iron. These rails preserve their magnetism even after they have been removed, but they lose it gradually. When in position, however, the magnetism is latent, only becoming free when the chairs are removed and disappearing again when they are replaced. Hence it is necessary to assume that two opposite poles come together at each junction, and that each rail is a magnet, the poles being alternately reversed throughout the line. This production of magnetism in the rails examined is undoubtedly attributable to the running of the trains and to the shocks, frictions, etc., thereby produced. The hypothesis of electric currents, induced or direct, must be rejected, since it is negatived by experiments upon the subject made with suitable apparatus. Although the interest attaching to the fact above stated is at present purely scientific, it is not impossible that the magnetism thus developed may exercise an influence actually beneficial upon the stability of the roadway, increasing the adherence to the rails and the friction. It is possible, also, that the magnetic currents may be stronger at the moment of the passage of the trains, than either before or after. If this be so, the observations may acquire a still higher practical importance.

Chemistry, Physics, Technology, etc.

NEW PROCESSES IN PROXIMATE GAS-ANALYSIS.

By Professor Henry Wurtz, of New York.

[*Communicated in part, with Experimental Illustrations, to the American Gas-Light Association, October* 22, 1874.]

Gas-analysis, in the widest and highest sense of the expression, comprehending the proximate analysis of gaseous mixtures, natural and artificial, as well as the ultimate analysis of gaseous compounds, includes what have heretofore been unquestionably the most difficult and delicate, while also, when correctly viewed, the most fruitful and promising branches of laboratory chemistry. It is also quite just to assert of these branches that they have of late years been far too little cultivated by many chemists of the first rank. It is to this that I would attribute the fact that your own great and noble art of Artificial Illumination—to which I might add those of metallurgy and furnace operations generally—linger in a stage of empiricism not in accordance with the actual advancement of chemical science. It may safely be alleged that we are now learning far more, and more rapidly, of the liquid and solid products of retorts, stills and furnaces, than of the gaseous products. This should not continue; and I venture to hope that the observations I have to offer may in some measure lead the way, and to some extent lay the foundation for the more diligent application of known chemical principles to the practical investigation of gaseous mixtures and products of the chemical arts.

The class of methods known by the rather insignificant name of Eudiometry, had so great an impulse imparted to it a quarter of a century ago by the genius of the illustrious Bunsen, that gas-chemists have really seemed to me to merit since, in some measure, the reproaches cast upon the immediate disciples of Aristotle of old, who believed their great master had probed the depths of possible human wisdom, and therefore refused to interrogate Nature further. It is

true that many of Bunsen's methods, apparatus and manipulations in gas-analysis will remain indispensable, and will stand as monuments to his fame, very little having been done since except in the way of modification, by other chemists; but there are nevertheless cases and conditions often of great importance, where all so-called eudiometric methods fail to satisfy the practical requirements.

One such case may here be entered into as an example. This is the determination of *air*, as a contamination of illuminating gas. It is well understood that each single proportion per 100, of air, destroys at least six per cent. of the illuminating value of an ordinary coal-gas. It is not easy then to exaggerate the importance of this case. But, in a eudiometer 500 millimeters long, one volume per 100 of air is but one millimeter of oxygen. A variation or error of observation of a single degree Fahr. of temperature, or of ·061 inch of barometer, down or up, will either double or destroy this determination. But by the methods I have now to propose, one cubic foot of such gas will yield, in a form amenable to the balance, 1·18 grain = ·076 gram of oxygen; and 5 cubic feet, ·3815 gram.

Moreover, in eudiometric oxymetry, the introduction of potassic pyrogallol into the gas under investigation, is always of necessity preceded by that of potassic liquor or potassic hydrate, to remove carbonic acid; and if this potash be washed out with water, say with a minimum, of 20 millimeters (in a eudiometer of 500 mm.), of the latter, this water will always abstract some of the oxygen sought to be determined. At 60°F. = 16°C., 20 mm. water can take up (Bunsen) ·59 mm. of O; or, in this way, as much as 59 per cent. of the oxygen (and air) sought may be altogether lost! I may add that, in working on coal-gas, the further possible, or at least supposable absorption, by this 20 mm. water, of ·29 mm. of N, ·39 mm. of H, and .48 mm. of CO gases—together with the ·59 mm. of O—1·75 mm. in all—might vitiate the CO^2 determination to the extent of 0.35 per cent. of the whole volume, in excess; which, in a coal-gas purified by lime, would be a vitiation quite fatal to the value of the analysis.

Some eudiometrists may reply that they do not wash out the potash with the water, before applying pyrogallol. If so, I must impugn their work on several other grounds:—for instance, will the film of potash liquor on the inner walls of the eudiometer occupy the same volume as a film of pure water? My own experiments have shown me that it will not. Again, either solid potash or strong potash liquor

desiccates the gas, thus introducing another very appreciable error. A conscientious original investigator who tests all methods rigidly himself, will devise ways to mitigate, if not to eliminate some of these difficulties; but this does not meet the practical requirements of the case, for all are not competent to do this.

The above is cited as but one sample of the multitude of difficulties with which every really competent eudiometrist must admit himself to be environed.* Special and complex devices have not been wanting —many of them of great and permanent value—to lessen certain difficulties; but it has appeared to me that in those cases—including many of the most important ones, as, for example, illuminating gases and gaseous furnace-products—in which the mixture to be analyzed is attainable in volumes practically illimitable; it would be well to try to cut loose from methods which are purely volumetric, and to devise such new ones as would enable us to deal with quantities that can yield ponderable products; thus appealing directly to that infallible criterion, the chemist's "court of last resort," the balance.

In this attempt, I have already met with success sufficient to encourage me to place the results before the chemical world, confident that some things will be recognized in them worthy at least of being followed up and brought to a further stage of perfection. This further pursuit of these paths of promise will be my own task so far as it may be permitted to me.

The methods I now put forth are founded on the general principle of submitting a slow current of the gas to be investigated to the action of a series of agents, so selected and combined as to absorb and separate, in succession, each by itself, the different proximate constitutents of a gaseous mixture, converting each into a solid or a liquid form, which can be weighed on a balance. About 1840, European chemists were using successfully methods of this class. One method, which arose at that time out of their experiments in this direction, was that still in use in "Organic Analysis," for separating

*I may be excused for here introducing the remark that I myself have endeavored to do my share with other gas chemists towards the emendation of Bunsen's system of eudiometry. My own efforts have been generally in the direction of simplification, acceleration, and more especially to attain (what I have always deemed) the great desideratum of a reduction of the needful amount of quicksilver to a minimum. I now use simple devices and manipulations which enable me to accomplish all the essential work of eudiometry with at the most 10 lbs., and chiefly with not more than 5 lbs. of the liquid metal. These will soon be submitted to the chemical world.—H. W.

in distinct and weighable forms water and carbonic acid. Strangely, however, the capabilities of these methods seem to have been looked upon as very narrow and special, and they have passed almost out of view. At the present day it is probable that a majority of chemists would not have anticipated, in advance, much satisfactory success in the application of these modes of procedure to such complex mixtures as crude coal-gas, or a furnace-gas. My experience has, nevertheless, tended to an opposite conclusion, and I believe that I discern, in this direction, the only practicable road to complete success in the proximate analysis of heterogeneous gases.

[In this memoir, I will here say, I must confine myself mainly to illuminating gases. The handling of furnace-products by these methods will furnish subjects for future communications.]

In a crude coal-gas, as drawn from the hydraulic main, over the retort benches, the following main constituents may be enumerated, which it is highly important that a gas-chemist should be competent to separate and determine with precision:

1. Tar, suspended in the form of spray.
2. Water, in similar mechanical admixture.
3. Water, as vapor, dissolved in the gas.
4. Naphthaline (condensable).
5. Other condensable hydrocarbons.
6. Smoke and soot (with dust).
7. Ammonia.
8. Carbonic Acid.
9. Sulphuretted Hydrogen.
10. Carbonic Oxide.
11. Oxygen, that is, Intermixed Air.

Of these eleven proximate constituents I have so far succeeded in separating, with very satisfactory sharpness, Nos. 1, 2, 3, 6, 7, 8, 9, and 11; eight in all, besides some approximation to No. 4, the naphthaline in excess. Nos. 5 and 10 are still subjects of experiment.

My success so far is to be attributed mainly to the gradual attainment and combination, by tentative experiment, of the following devices and manipulations.

First—Arresting suspended matter by means of empty dry flasks and straining through cotton previously *desiccated*.

Absorbing next, the ammonia, by means of reagents which act on no other ingredient.

Next, drying the gas with calcium chloride, which, ammonia being absent, may now be done.

Next, taking up the sulphuretted hydrogen by a normal metallic salt, so selected or so managed as to give up no water or acid vapor to the desiccated gas.

Next using sodic hydrate to absorb the carbonic acid, with certain precautions described below.

Next, alkalized pyrogallol or other suitable agent, to absorb oxygen, arranged so as to lose no water.

In the case of illuminating gases—with some few others—the final (rough) measurement of the gas is then made at an observed temperature by a gas meter; if with a dry meter, directly; if with a wet meter, after saturation with moisture at the temperature of melting ice.

In the latter case, of a wet meter, the amount of final moisture in the gas is determined by a reiterated desiccation with calcium chloride.

The whole process is finally completed and the separations rendered as sharp as may be, by a process of distillation, either at the ordinary or higher temperature in a current of the same gas analyzed, that has been previously subjected to the same or similar treatment and thus freed from all the ingredients to be separated from each other.

After final weighings, the *correct* initial volume of the gaseous mixture is calculated by certain formulæ derived, as specified below, from the crude meter-indications and the final weighings.

I shall now proceed to an attempt to explain (simultaneously to save space) the details of the methods as applied to each constituent, and those of the construction, preparation, and arrangement of the different pieces of apparatus, as connected and represented in the figures.

I. Analysis of Crude Gas, in the Gas-House, before Purification.

The mechanically suspended Tar and Water. The joint devices for arresting these two substances, in the first instance, are shown in Fig. 1, letters A to F inclusive. A indicates an inch-thick soft-rubber cork, with two perforations, occupied respectively by a thermometer and an eduction-tube bent at a right angle, inserted into an aperture bored through the wall of the hydraulic main or of any other main in the works. This eduction-tube must at once descend, to

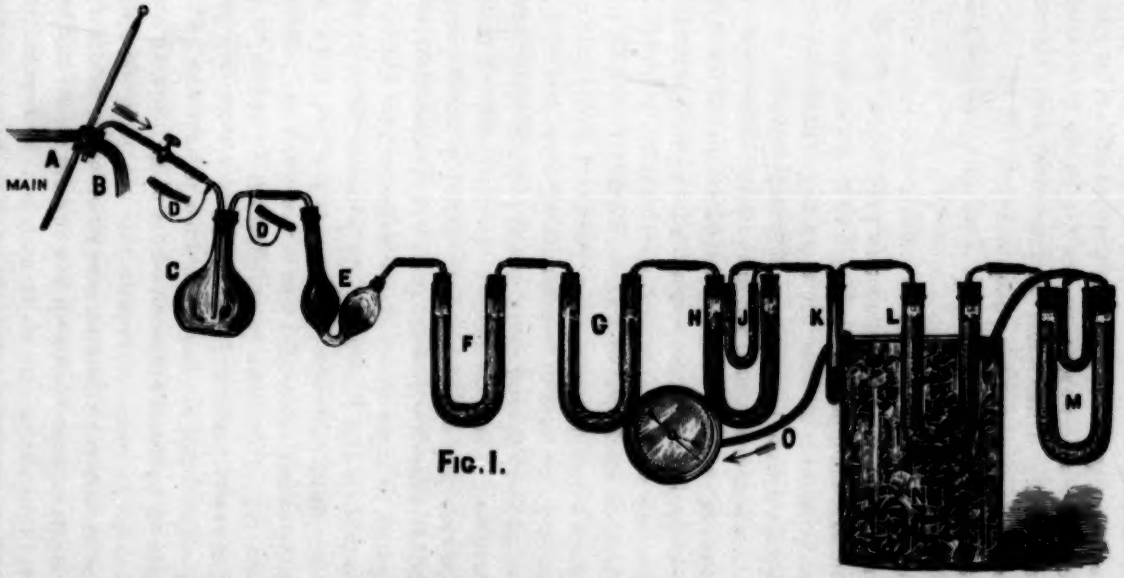


FIG. I.

TRAIN FOR THE ANALYSIS OF CRUDE MIXED GASES: FROM THE HYDRAULIC MAIN OF A GAS WORKS, ETC.

[NOTE.—Between G and H an additional tube, precisely similar to G, charged with *chloride of calcium*, is employed, which for simplification, has been omitted from the figure.]

allow liquids to flow into the flask, and must have a stop-cock in it. The first member of the train is an empty dry thin glass flask C, which collects almost the whole of the spray, aqueous and tarry. DD are two stoppers for closing C hermetically, constructed of pieces of rubber tube closed at one end by short sections of glass rod. The bent wires by which these are permanently attached to the flask had better be of iron than of copper, as they are to be weighed with the flask, and the latter metal is quickly blackened and may be slightly changed in weight by the sulphide of ammonium that pervades the atmosphere of the gas-house. In a permanent apparatus, for nicety, platinum wires had better be used. Copper wires, however, used here, and in other parts of the apparatus, may be protected pretty well by coating with collodion, or even with a film of paraffine. [All the brass stop-cocks I use in these and all other operations with sulphuretted gases, I prefer to plate, inside and out, with nickel, which protects them perfectly against sulphur. This nickel-plating every gas-chemist will find it well worth his while to perform for himself, as it is *very* easy to accomplish, in case of brass and copper surfaces, with slight practice. I propose publishing a note which I think will lead any laboratory worker to success in his first trials.]

These trains of apparatus are probably most conveniently set up by being suspended to a strong wire—best of soft copper—stretched tightly between two convenient points of attachment. To make this wire tense or "taut," it had better be in two pieces, attached first at the extremities, then twisted together strongly and warily with pincers at the point of meeting. The tubes are hung on inverted V-shaped (Λ) wires bent into hooks below. These, for simplicity, are not figured. All the rubber tubing used as connectors, I wash laboriously, internally and externally, in a rapid current of water with hard rubbing between the hands, until absolutely clean, then rub dry, and lubricate, within and without, with thick syrupy glycerin. The excess of this being wiped off, the tubing is found permanently more flexible, far less liable to abrasion of surface, more easily slipped over ends of glass tubing, and, above all, has its capacity for absorbing certain constituents of the gas reduced to a minimum. All the corks should be rubber, scoured and glycerated superficially in the same way. The cork at A—owing to the heat and actual contact with tar—and, to a less extent, the cork of flask C, are somewhat penetrated and soft-

ened, so that A gives out, after being used a number of times. The others last indefinitely.*

E and F are stuffed, uniformly, but as loosely as practicable, with cotton, which is best inserted and gently packed down, in successive small wads, picked out before insertion. The bulbous pattern, like E,† may present here some advantage, but it is not at all essential. Its use, as photographed in this case, was in order to bring down somewhat the level of the rest of the train. I have used, and prefer, a compound cotton apparatus, or two tubes of the size of F, united by a twisted wire in the manner of A in Fig. 4. These can be weighed together conveniently.

Even in case of a gas that has passed through condensers and scrubbers, it seems necessary to use two tubes of cotton. In one actual series of analyses, of unpurified coal-gas before and after having passed the scrubbers and condensers, the second tube F, increased, on an average, in weight (all moisture having been removed) from the uncondensed gas ·128 grain, and from the condensed ·072 grain, per cubic foot of gas passed, up to 7 cubic feet. The main consideration here is the initial *pressure* at command, of the gas. If the customary exhauster is employed in the gas-works, and kept at work during the analyses, the pressure between the exhauster and the retorts may be found so low that a train attached between these, may not admit of more than one cotton tube, and even this packed as loosely as possible. At points beyond the exhauster, however, this trouble seldom occurs; it having been necessary indeed, in some such cases, with unpurified gas, to partially close the cock in the eduction tube, to bring down the rate of flow through the train to about one cubic foot per hour, which it should not in most cases exceed.

The Ammonia.—In order that we may employ, for dehydration, the highly convenient, powerful, and reliable agent, chloride of calcium, it quickly became apparent to me, in my earliest experiments, that the ammonia must first be abstracted from the gas; and my first efforts were to decide upon the proper agents that could be used,

* All these corks should be of the *best* quality made. Many in the American market are very poor—indeed, useless, for this kind of work.

† I may say here that E, as shown in the cuts, was in the condition left after having been used, and in drawing from the photograph, an attempt has been made, none too successfully, to reproduce the shading of the arrested soot.

in solid form, for this absorption. One of these I have sufficiently tested, by quantitative as well as qualitative experiments, to demonstrate its entire applicability to this use; namely, fused *potassic bisulphate*. It is proper for me here to state that the earliest preliminary experiments with the bisulphate, were made, at my suggestion, in the course of an investigation carried on jointly by Prof. B. Silliman,* Dr. S. D. Hayes and myself; in which we desired to absorb the ammonia of crude coal-gas. We all became convinced, I believe, that potassic bisulphate had the power to take out *qualitatively* the NH^3 from gas; but the precautions essential to success, in a quantitative way, have been since worked out by myself alone.

The mode of preparation of the bisulphate is by simply cracking in a mortar to the average size of wheat-grains, and removing the dust and finer particles by a sieve of eight holes to the inch. The dust is very painfully irritating and injurious, and its inhalation must be avoided, if possible.

[Though many chemists seem somehow to have acquired the idea that bisulphate of potash possesses more or less *deliquescence*, it in reality has none of this quality whatever, and it is not even hygroscopic, to any remarkable extent.]

It must not be supposed that the bisulphate takes up ammonia as NH^3, which would involve a very important error. The compound formed, as desiccated for the final weighing, is the double sulphate of potash and oxide of ammonium. The factor *am* in the equations below must be obtained, from the increase of weight, by multiplying by a coefficient = ·70833. And it may here be remarked that a part of another factor *wv* comes likewise from this increase of weight, through multiplying it by ·29267. This ammonia-tube is lettered G.

The Water.—Chlorde of calcium for absorbing this, comes next in our Fig. 1 train, though, as it would be merely a duplicate of G. the CaCl tube has been omitted from the cut. I prefer, after trying many preparations—a *fused* chloride, assuring myself, above all, that it is free from every trace of causticity, and crack it up to the size of small peas, sifting out all that passes a sieve of six holes to the inch.

* Prof. Silliman has also since worked by himself on this or a closely related subject, and made a communication to the National Academy, at the late Philadelphia meeting, to which I would refer. Prof. S., I believe, experimented chiefly on the utilization of crude commercial bisulphates, generally of soda, called "salt cake" in commerce; for the technical extraction of ammonia from gas.

For the small CaCl-tube J, the one in M (Fig. 1), and J and L in Fig. 4, I find it desirable to crack but little, if any, smaller; to avoid risk of obstruction.

The Sulphuretted Hydrogen.—For this constituent I have tried several absorbents, but none as yet that answers, on the whole, so well as common crystallized blue vitriol, cracked and sieved to wheat-grain size. As in desiccated air it slowly loses some of its water (Graham found that in fine powder, over oil of vitriol, it lost in seven days 3 of its 5 water-equivalents) I add a small calcium chloride tube, which is of course weighed with it in all cases. The test-tube K, containing a slip of lead-paper belongs (qualitatively) with the cupric-sulphate tube H.

With crude gas from highly sulphurous coals it may sometimes be prudent to duplicate this member of the train. Of course the small CaCl tube J need be added only to the second one. The increase of weight in this member is of course HS. If to be calculated as simple sulphur, as sometimes required, it must be multiplied by ·9471.

The Carbonic Acid.—The agent which combines, for this absorption, the greatest advantages by far, is that form of sodic hydrate now so common in commerce, cast into pencils, and labeled "soda by lime." In this class of operations the weight of CO^2 to be absorbed is often very large. In ten cubic feet of crude coal-gas containing 2 per cent. by volume of CO^2, there is about 172 grains by weight of the latter, which requires for absorption (if normal carbonate be formed) near 315 grains of sodic hydrate. Although some bicarbonate is usually formed, yet the absorbing surface required is large. Potassic hydrate, prescribed in the books, is wholly out of the question for these methods. The solubility of KO,CO^2 is so great, especially as much heat is always developed during the CO^2 absorption, that the water of the hydrate serves to melt the mass into a magma and quickly to obstruct the flow. In cases where mere abstraction of CO^2, without weighing, is the object, one large tube containing 10 or 12 ounces of sodic hydrate—as in H, Figs. 2 and 3—may be employed; but in the case under consideration, two tubes must be used, containing each 5 or 6 ounces, to reduce within conveniently weighable limits. These are here lettered L and M.

(To be continued.)

DILATATION OF CAST IRON AND THE PHENOMENA OF THE CRANE LADLE.*

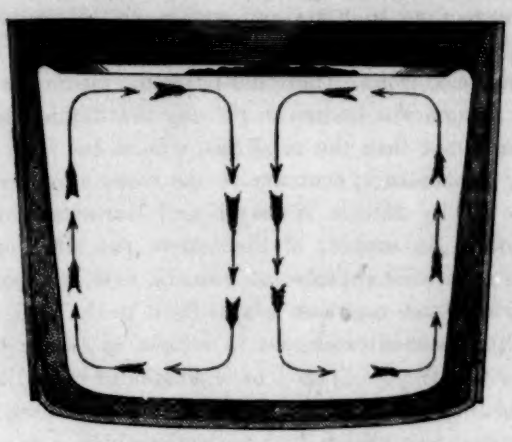
By Robert Mallet, C. E., F. R. S., etc.

In my former paper on this subject—*The Engineer*, Sept. 11th—the linear dilatation of bright gray cast iron between 60° Fahr. and 2400°, the assumed temperature at which such liquid cast iron is usually poured into moulds, was deduced as equal to 0·02606 of the unit length. The temperature at which the iron is poured is, however, necessarily above the melting point, and in my experiments this excess may be estimated at 200° Fahr., deducting which from the total range of temperature of my experiments, viz., 2400°—60°, gives for the entire range of temperature between 60° and the melting point = 2140°, the total dilatation corresponding to which is therefore 0·0234, which is approximately equal to 9-32 in. per foot in length. The average allowance made by pattern makers for "shrinkage," deduced from long experience, varies from 4-32 in. to 6-32 in. per foot in length of the pattern, and with some highly contractile cast irons—such as the No. 3 Blaenavon pig, much used for engineering castings some years ago—to about 8-32 in. The actual dilatation as thus determined experimentally exceeds the excess in dimensions given to patterns in accordance with the empiric rules of pattern makers; but the linear dimensions of the sand mould are not determined by those of the pattern alone, but exceed these by the amount of "rapping" or shaking in the sand necessary to free the pattern, and enable it to be "drawn" therefrom. The mould thus exceeds the dimensions of the pattern by an uncertain and variable linear amount, varying with the absolute size and form of the pattern, the delicacy of manipulation of the workman and other circumstances. And as we see the enlargement of the mould produced by this "rapping" may amount to almost as much again as the excess in dimensions which the pattern maker allows in the pattern, we may thus readily observe the futility of the statement made in many works on metallurgy that the pattern makers' allowance for "shrinkage" affords a criterion for fixing the total dilatation of cast iron. Although I

* Reprinted from the London *Engineer*.

have been thus enabled to determine experimentally for the first time the actual dilatation of that most valuable variety of cast irons, namely, that close bright gray iron employed by engineers for structures and machinery, much more remains to be done, and I hope will be done, by other experimenters before the subject can be considered as complete. The total dilatation of white crystallized cast iron, and of the very soft large grained and almost black cast iron which occupy the two extremes as to dilatation, remain yet to be experimentally determined, as well as the effects of very rapid or very slow cooling upon the same cast iron. These did not come within the scope of my own inquiry, which was limited to proving that liquid cast iron is not more but less dense than the same cast iron in the solid state and at atmospheric temperature, contrary to the views often expressed, and prominently so, by Messrs. Nasmyth and Carpenter in their work upon the moon. In support of their views two different sets of collateral facts have been appealed to, namely, first, the notion that the perfection with which cast iron adapts itself to the form of the mould arises from its assumed expansion in volume at the moment of consolidation or "setting." This I have treated of in my last communication—*The Engineer*, 11th inst.—and shown that there are sufficient reasons why cast iron affords such perfect castings, irrespective of any delusive appeal to such expansion in volume, which has been proved not to have any existence. Secondly, another class of facts, viz., those presented by the circulatory movements noticeable in large masses of liquid cast iron, have been appealed to in support of the erroneous notion of the increase in density in cast iron with increase of temperature above the melting point. When a large, clean and newly-lined crane ladle, containing eight or ten tons, is filled from the furnace, and left to repose, circulatory currents may be observed to set in more or less energetically in the liquid metal. It is scarcely necessary to state in *The Engineer* that the crane ladle is a nearly cylindrical vessel, with a flat or slightly convex bottom formed of thick boiler-plate, and that it is lined in the inside with plastic clay and sand mixed with other materials and dried perfectly, so as to form a badly conducting stratum between the iron of the ladle and the mass of molten metal which it holds, the exposed surface of the lining being usually black-washed with powdered coal and water. When the directions of the currents in such a ladle are observed, it is

found that they move upwards about the exterior or sides of the metal, that at the surface they pass inwards convergingly towards the centre, and may be inferred thence to descend about the central portions of the liquid mass, and arriving at bottom of the ladle, pass outwards divergently, to be again carried upwards at the sides—these directions being such as are shown by the arrows on the adjacent figure, which is nearly similar to that given by Mr. Nasmyth in the



work above mentioned. These circulatory currents are attributed by him to the cooling of the mass, and on this assumption he correctly argues that as the cooling takes place chiefly from the bottom and sides of the ladle by radiation and by evecting currents of air, and as the currents are upwards at the sides of the ladle where the iron is coldest, so the specific gravity of the iron thereabouts must be less than that of the hotter central parts of the mass, whence he concludes that the cast iron itself dilates as it cools in place of contracting, for if it contracted the currents must be in the reverse directions to those indicated by the arrows in the figure. No fault whatever can be found with this reasoning, provided we admit the assumption upon which it rests, namely, that the currents observed are produced by cooling alone, that is by the difference in temperature at any moment between the circumferential and the central portions of the liquid mass. In a paper on this subject read before the Royal Society last session, and which will be published probably about the end of this year, I have pointed out that, considering the density and viscosity

of liquid cast iron, and the small amount of its contraction per degree Fahr., no such currents as are observed in large crane ladles could be produced by cooling at the rate at which that actually proceeds in such masses. The currents, however, are there, and usually in the directions shown in the above figure. From what, then, do they arise, if not from cooling? They really originate in the ascending current of gases and vapor given forth by the material of the lining when exposed to the high temperature of the liquid metal. The clay and sand are mixed sometimes with pulverized coke and with chaff or plasterers' cowhair, or other fibrous matter, to give it coherence before being dried, and sufficient openness of texture not to blister or split off or part from the ladle when suddenly heated. All the materials of the lining, therefore, except occasionally the sand, evolve torrents of gases and vapors as soon as the lining is exposed to the roasting contact with the liquid metal. Clays, which are natural hydrous silicates, and contain mechanically suspended as well as chemically combined water, when exposed to a bright red heat evolve these as highly heated steam. The coal wash, the coke dust, and the organic matters present, are more or less rapidly torrefied and converted into carbonic oxide and acid, vapor of water, and several other volatile vapors or gases. Innumerable streams of these are evolved and stream up through the liquid metal most rapidly and copiously where that is in contact with the largest proportionate surface of the lining, giving rise to the ascending currents at the sides of the ladle as seen in the figure, and the upward movement of which necessarily results in the creation of the convergent surface, the descending central, and the divergent bottom currents. That this is the true solution of the production of these currents is conclusively shown by the following facts. Large ladles are usually lined afresh every time they are used; if, as often happens, the metal filling such a ladle be tapped at too high a temperature, and be let to repose for a considerable time until its temperature be suitable for the purposes of the founder, it may be observed that the energy of these circulatory currents sensibly diminishes, so that in a ladle of eight or ten tons they almost cease to be observable, and in much smaller ladles may be occasionally seen to be reversed in direction though with enfeebled energy. It occasionally happens, however, that a large crane ladle is required to be filled with metal a second time before the lining has ceased to be hot. In this case almost no currents are produced, and such as may be remarked

are not in the directions shown in the figure. The volatile matters contained in the lining material having been by the double heating completely driven off, the ascending circumferential currents cease to be produced. The phenomena of the crane ladle, therefore, when rightly interpreted, present no corroboration whatever of the erroneous supposition that cast iron becomes denser as its temperature above its melting point is higher. It is to the nature of the gases and vapors generated from the materials of the lining, and chemically reacting upon the liquid iron as they stream up through it, as well as to the action of the atmosphere upon the constituents of the cast iron itself at the surface of the molten mass, that are to be ascribed those curious starting and vermicular movements visible upon the surface of a ladle of liquid iron, and known amongst founders as the "breaking" of the metal. The vapor of water as it streams upwards is partially decomposed, and its oxygen oxydates some portions of the cast iron while its hydrogen deoxydates others. The gases generated from the organic materials present produce like reactions. At the surface of the molten metal the oxygen of the atmosphere oxidates some of the silicon present, producing a film of silicic acid which rapidly combines with the oxide of iron or of other metals also on the surface, producing thus continually a pellicle of fused silicate of iron which breaks and aggregates itself to any little globular particles of slag or silicate already formed and floating on the surface; and as in numerous other examples where opposite chemical reactions are going on at different points in the same liquid mass as here, oxidation and deoxidation, those starting movements are visible which are the indications of sudden overthrows of chemical equilibrium.

This is but a very brief sketch of the causes of those curious movements seen in the "breaking" of cast iron, and in many other metals having high melting points and of ready oxidation and reduction which have been long observed, but not, that I am aware of, previously been attempted to be explained. They present many points of high interest to the chemist and molecular physicist, and present a fertile field for fuller investigation, but the subject is of theoretic rather than of direct practical importance.

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